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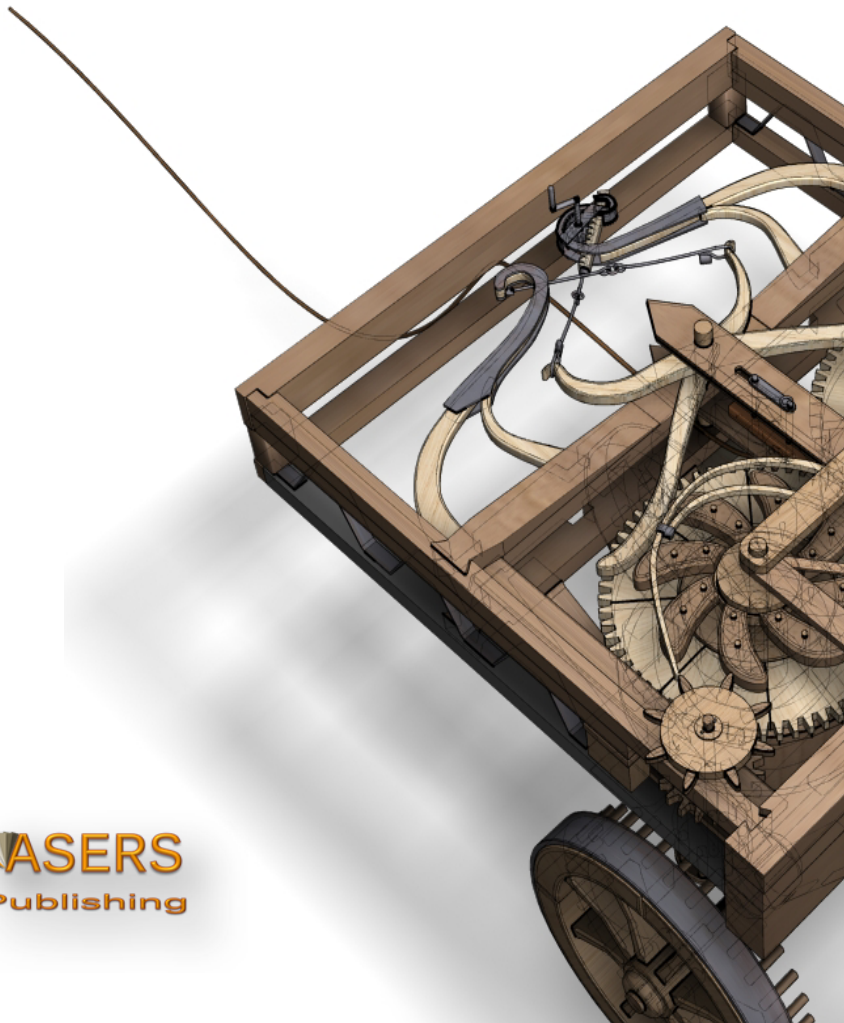
Journal of Environmental Management and Tourism



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QR Code Use and Identification Problems in Tourism

József UDVAROS
Budapest Business University, Budapest, Hungary
udvaros.jozsef@uni-bge.hu

Norbert FORMAN
Budapest Business University, Budapest, Hungary
forman.norbert@uni-bge.hu

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Abstract: The integration of technology with tourism increases its efficiency and improves the tourist experience, especially through QR codes and NFC technologies, which are already widely used. The number of research related to digitization and the sustainability of tourism is increasing, and the focus is shifting towards ICT, AR and VR. Mobile services like QR codes are crucial in tourism, improving service availability and user experience. The article analyzes the importance of QR codes and image processing in logistics and tourism. The focus is on the technological foundations, recognition, and decoding methods of QR codes, highlighting the role of artificial intelligence. The article discusses in detail the application of QR codes in tourism, along with technological challenges and development opportunities. It also presents future research directions and the potential effects of QR codes on tourism.

Keywords: QR code; code recognition; tourism; artificial intelligence.

JEL Classification: L86; L83; D83; Z32.

Introduction

Technology permeates all areas of life, so it is a logical step to integrate it with tourism in order to improve its characteristics and make the experience of tourists simpler and problem-free. Quick Response (QR) codes and Near Field Communication (NFC) technologies are already widely used in various fields, such as inventory systems and online payment solutions (Gubán and Udvaros 2022).

In recent years, the number of research conducted in the field of digitalization and the socio-economic sustainability of tourism has increased significantly, which indicates that this research area is receiving more and more attention. The researches of the last decade have presented many empirical studies on this topic. The bibliometric analyzes show that the focus of research has shifted to exploring the field of ICT (Information and Communication Technologies), especially AR (Augmented Reality) and VR (Virtual Reality) within the social and economic sustainability of tourism (Forman and Udvaros 2023).

Mobile services play an increasingly important role in many aspects of our daily lives, especially with the spread of mobile internet and more advanced mobile devices. This is especially true in tourism, where mobile tagging, such as the use of QR codes, can significantly improve the accessibility of services.

1. Methodology

In the article, we conduct a short literature review during the research. As a source, we review articles from several scientific databases. First, we examine the technical articles in the field of digitalization and the socio-economic sustainability of tourism. We examine what results other researchers have achieved internationally in the given field. We look at the impact of ICT on tourism, focusing on the use of QR codes, VR and AR technologies.

After that, we describe in detail the application of QR code recognition and image processing techniques in the fields of tourism. During the research, various image processing methods and artificial intelligence-based algorithms are applied, which enable the effective recognition and decoding of QR codes in different conditions.

We present how QR codes can be used to improve the visitor experience of tourist sites and to increase the efficiency of logistics processes.

Finally, we present the problems that appear when recognizing the QR code, for which we propose a solution.

2. Literature Review

Indonesia's Weh Island has many natural tourism opportunities that can contribute to increasing the income of the local community and provide valuable lessons for those living in volcanic areas. Traditional information provision is limited to guidebooks for tourists, in which guides explain the attractions and their significance. In their research, the authors of the article (Yanih *et al.* 2023) developed a digital tourism system that, by integrating QR codes and web-based technologies, provides more information to visitors and is easy to use for local residents as well. According to data analysis, the number of monthly visitors to tourist sites can be tracked using QR code information boards supplemented with a web programming system. With the javascript integration of QR code boards, visitors can access changing information such as links, images or videos without having to reprint the QR code. In addition, the research presents the main sites of Iboih village in Web-GIS format, including tourist attractions, road access, public infrastructure and dining options that are easily accessible to tourists. Based on their research, they came to the conclusion that the integration of QR code and web-based programming can be an effective option in the field of tourism development as a study tool that can be used by the community.

In their research, the authors of the article (Ekundayo *et al.* 2023) want to develop tourism in the Southland region of New Zealand using Quick Response (QR) codes and Near Field Communication (NFC) technology. The purpose of the QR Code and NFC Bases Information System (QNBIS) presented in their research is to help tourists by providing information about the attractions in the area, thus making their trip easier and more enjoyable. By scanning QR codes or reading NFC tags with a mobile phone, the system provides visitors with a presentation of the locations. Considering the threat of malicious use of QR codes and NFC tags, their research also proposes a security strategy that includes three specific implementation methods. Their research also includes the implementation and evaluation of the QNBIS prototype (POS), according to the results of which the QNBIS system effectively provides tourists with practical and safe information about the surrounding points of interest.

Australia is known for hosting major events such as the Australian Open, which attracts sports fans from around the world to experience the adrenaline-pumping atmosphere and world-class competition. As technology evolves, tour operators must adapt to stay competitive. The authors of the study (Tushar *et al.* 2022) use the content analysis method to examine how technological innovations affect Australian sporting events. The research finds that content sharing on social media, sharing platforms such as Airbnb and Uber, payment systems such as PayPal and Apple Pay, applications for information about nearby offers, and virtual reality for virtual tours of hotels they all increase the attractiveness of sports events. It is expected that sporting events with the help of technological applications will continue to be successful in the coming years. In their study, the authors recommend further research to measure the impact of technology on other Australian sporting events.

Penang is an important tourist destination in Malaysia. The most important contribution of the research presented in the article (Abumandil *et al.* 2022) is the exploration of the variables that can play a role in the development of smart tourism, with particular regard to mobile augmented reality applications and the use of social media. The study not only expands knowledge from a theoretical point of view, but also has practical and educational implications for travel agencies, potential customers, government officials and the long-term sustainability of smart tourism. The research also emphasizes the importance of adopting smart tourism. Smart tourism provides services that offer benefits not only to local visitors but also to international audiences, such as tourism and smart travel. In intelligent tourism, these services serve both tourism stakeholders and tourist attractions. Featured services include the display of online interactive content and information, such as culinary offers, handicrafts, performing arts, tourist villages and other ICT-based services for tours. As part of smart tourism, they help provide interactive and informative experiences, including online availability of prices, opening hours, contacts and visitor reviews.

In their study, Jiang and Phoong examined the impact of digitalization on the social and economic sustainability of the tourism sector through a systematic literature network analysis. According to the results, digitization has a positive impact on economic sustainability, including tourism product development, consumption and industrial development. Digitization contributes to social development, cultural awareness and tourism participation in the field of digital technologies and cultural heritage. The study used bibliometric analysis to identify publication trends and research hotspots. The study produced two main conclusions: the identification of

knowledge gaps and evidence-based decision-making based on previous literature. The research also makes recommendations for future research that can help policy makers, tourism planners and researchers develop research-based strategies. The results emphasize the importance of digital technology in the sustainable development of tourism. Researchers and industry experts are increasingly investigating the potential and effects of new forms of ICT in the field of tourism. AR and VR technologies are particularly relevant as they offer new opportunities to personalize experiences and interactions, which can significantly affect the social and economic sustainability of tourism (Jiang and Phoong 2023).

In their article with Canadi's co-authors, they present the possible applications of QR codes in tourism, specifically in the Mercedes-Benz Museum, and evaluated them in the test user study after the implementation of a prototype. According to the results, the use of QR codes potentially increases both usability and the intention to use services. QR codes provide convenient access to mobile content and services that can enhance the visitor experience. This can be a significant advantage for tourism, especially in cultural institutions, where visitors often seek information and context for exhibits or experiences. Incorporating QR codes and similar mobile tagging technologies into tourism services can increase visitor satisfaction and frequency of service use. An additional advantage of such technologies is that they offer a simple and cost-effective solution for tourist sites to update content and share information effectively (Canadi *et al.* 2010).

In their research, Mariotto and his co-authors present an innovative historical virtual geotrail that stretches along the eastern side of Mount Etna (Italy). This trail includes significant geological sites and features from the 1928 eruption. The "virtual geostops" of the virtual geotrail have become accessible to volcanologists, educators, the general public, tourists and volcanologists. These stops can be accessed using QR codes, which visitors can find on the printed or electronic documents and on the supplementary posters. The virtual geostations were created using the SfM (structure-from-motion) photogrammetry technique developed from images captured by unmanned aerial vehicles (UAV). The main result of the project is a virtual geopath consisting of eight geostops, divided into two parts, which presents outstanding examples of geological phenomena created during volcanic events. Their goal was for this approach to complement traditional earth science fieldwork and classic field trips, not only now, but also in the future. This virtual approach allows visitors to explore and study this fascinating geological area in an interactive and visually rich way, without being physically present at the site (Mariotto *et al.* 2023).

Drones are also a breakthrough technology in tourism, as they enable real-time, fast and accurate monitoring, while minimizing costs and with their help, we can also virtually visit areas that are dangerous for people. Nowadays, the use of drones is regulated by laws and regulations (Bódi 2023; Udvaros and Bódi 2023).

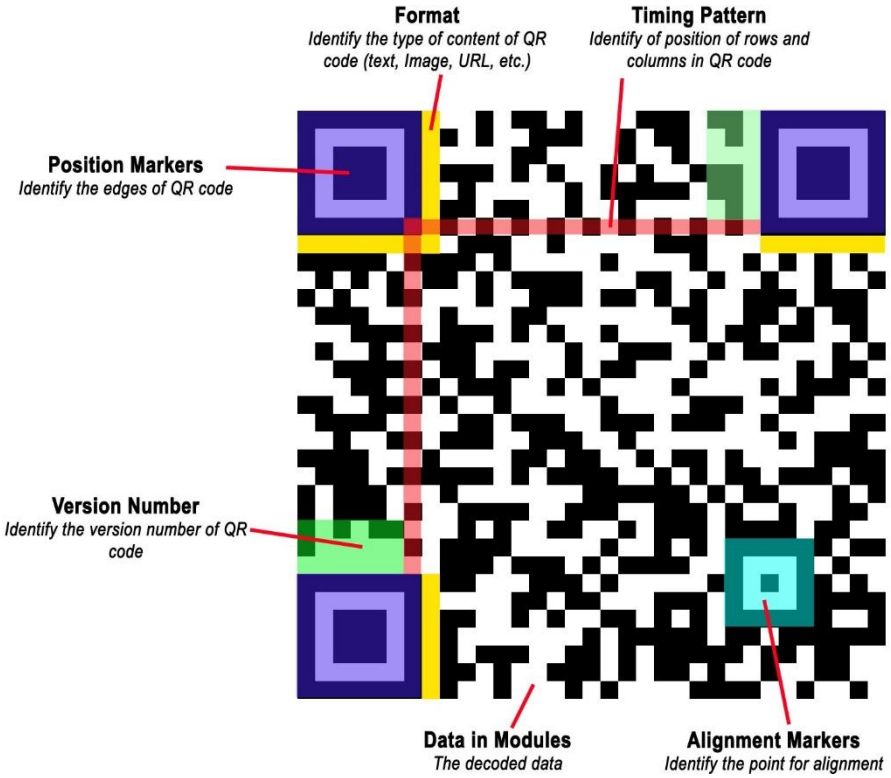
It can be seen from the articles that there is a serious potential for the application of information technologies in the tourism sector as well. To put it simply, for the layman, all you need to do is place a QR code near the given tourist location and scan the QR code with a smartphone. After that, use the information stored in the QR code to visit the website of the given location, where we get the desired information in the form of text information or with the help of VR and AR.

What exactly is a QR code?

QR codes can encode numeric, alphanumeric, kanji characters and binary data. There are 40 different versions of the QR code. Version 1 means a QR code that consists of 21x21 modules. If we take version 40, the 2D code consists of 177x177 modules. The relationship between size and version can be expressed as Size = 21 + (version-1)x 4.

Each QR code version has a maximum data capacity based on data volume, character type and error correction level. For example, a minimal version 1 QR code (where there are 21x21 modules) has a capacity of 10 alphanumeric (or 17 numeric) characters at the highest (H) error correction level. By comparison, the maximum version 40 (has 177x177 modules) has a capacity of 1852 alphanumeric (or 3057 numeric) characters at the highest debug level.

Figure 1. Constituent elements of the QR code



Source: Created by the authors

1. Position Markers: This is the position sensor of the QR code, which is formed by a darker square on a lighter square. They determine the position and orientation of the QR code.

2. Timing Patterns: An interconnected series of dark and light elements. They determine the size, the number of rows and columns, and we use them to identify distortions in the QR code.

3. Version Number: This is used to identify the version number of the QR code.

4. Format Identifiers: This identifier contains information about the mask pattern number and error correction level, which is necessary to decode the QR code to identify the type of content, such as URL, text, image, etc.

5. Alignment Markers: The alignment markers determine the alignment point in the QR code, which can be used to identify the distortion.

6. Data in Modules: The data encoded in the QR code is decoded using this indicator. If the QR code is damaged, it can be restored and read using the error correction method (Automatic Identification and Data Capture Techniques - QR Code Bar Code Symbology Specification 2015; Shettar 2016).

3. Research Results

Image recognition of QR codes provides a quick and convenient access point for users to information or websites. This procedure eliminates the need to manually type in URLs, making accessing information much easier and faster. Users can simply scan the QR code with their mobile device's camera and instantly access the content or services referenced by the code. This interactive and user-friendly approach improves the experience, especially in the fields of marketing, advertising and tourism, where QR codes can create a direct connection between users and products or services.

Automatic QR code recognition on smartphones is a complex but user-friendly process that uses the device's built-in camera and special software algorithms. When the user points the camera at a QR code, the camera lens focuses the light while the sensor digitizes the image. At this moment, the image processing algorithms are activated, which immediately recognize the characteristic pattern of the QR code, such as the three special corner marks and the information squares inside them. The software then decodes the content of the QR code, which usually contains data encoded in a standard format. After the recognition process is successfully completed, the user interface of the smartphone provides an indication to the user, often in the form of a pop-up window or notification, informing them of the successful scan of the QR code and the information

contained therein. Finally, the user can choose what action to take on the information provided by the QR code. For example, if the code contains a web address, it is possible to open the linked page in the mobile browser. Other types of data, such as text information or contact information, are displayed directly on the screen. This whole process is extremely fast and efficient, allowing users to use QR codes easily and quickly. This capability of smartphones significantly improves the convenience and efficiency of digital interactions.

3.1 Steps of Image Processing

Nowadays, QR code recognition technology is a popular topic in the field of digital image processing. With the constant development of IoT (Internet of Things), the QR code is increasingly used in various industries, even in tourism, due to its large information storage capacity and the use of reliable and secure coding technology. It is important to note that most of the time the QR code occurs in a non-optimal position (shape). For example, if the code is fitted to a cylindrical or spherical shape, it can be found in 3D on a square. It may also happen that we cannot read the QR code at the right angle. It is then necessary to perform corrections and image pre-processing. In most cases, recognizing the QR code consists of the following steps:

Figure 2. Image processing process

Source: Created by the authors

3.2 Localization - Recognition of QR Codes from the Image

Recognizing QR codes from an image is a complicated task. Nowadays, there are several different ways to solve this problem. One of the most well-known and widespread methods is the use of the Viola-Jones object detection framework. The mentioned framework provides an efficient way to focus the detection process on specific parts of the image. They focus on the Position Markers and Alignment Markers found in the three corners of all QR codes, where they perform an extensive investigation based on search patterns using the framework (Viola and Jones 2001).

Szentandrási and his colleagues deal with the detection and recognition of QR codes in high-resolution images. A real-time detector is provided on high-resolution (several megapixel) images. They present an efficient algorithm for detecting possible occurrences of QR codes. Their algorithm must be followed by an accurate detection/recognition algorithm. The use of a matrix code detection and recognition algorithm based on Hough transformation is recommended, since the information calculated with our new pre-detection algorithm can be reused, and thus a further reduction of the calculation requirements can be achieved (Szentandrási *et al.* 2013).

3.3 Correction of QR Codes

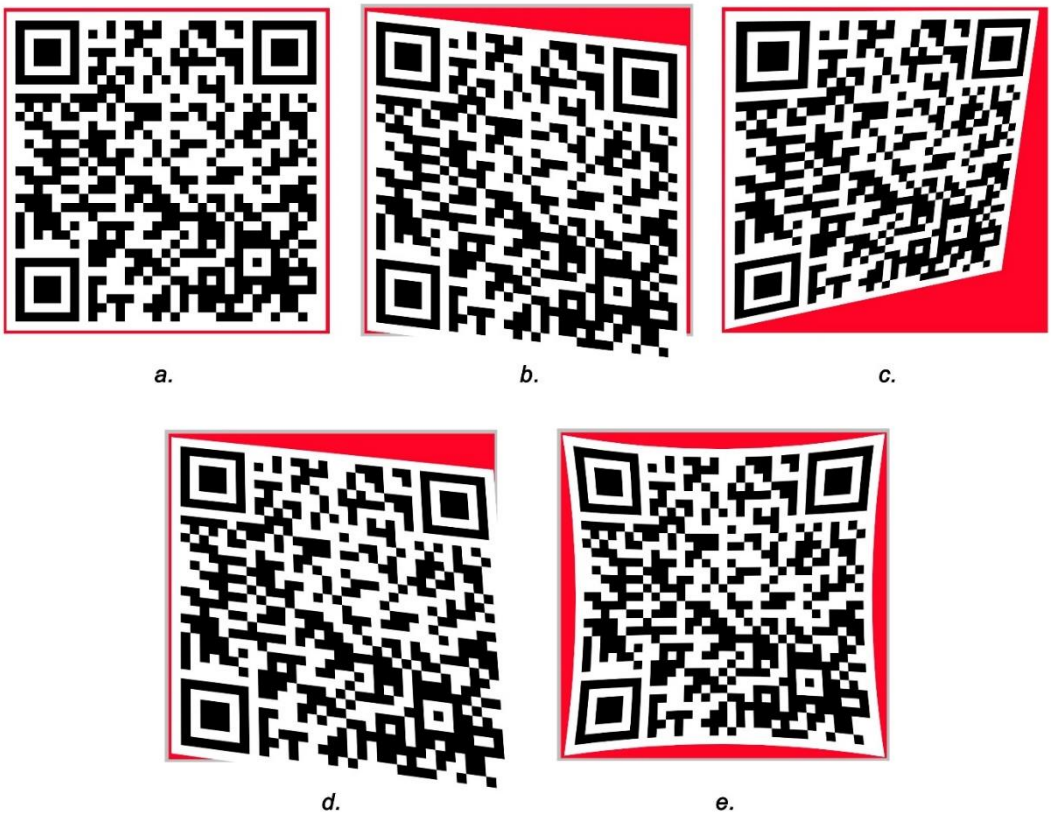
In most cases, the recognized images must be subjected to image pre-processing in order for the decoding algorithm to recognize the QR code, since the algorithms can recognize and process the code based on standards. Most of the time, the following corrections need to be made: clean up, correct blurring, skewing and bending. We know different methods for these, such as geometric perspective transformations.

Karach *et al.* propose an accurate and fast method for placing perspective-distorted 2D QR codes on arbitrary images under different lighting conditions. This method is suitable for localization of single or multiple QR codes on low-resolution images, as well as for real-time processing. The proposed methods use typical position detection patterns of QR codes, called search patterns, to identify the three corners of QR codes in an image. Distorted QR codes require perspective transformation. The optimal position of the fourth corner of the QR code is determined by analyzing the direction of the horizontal and vertical edges and maximizing the standard deviation of the horizontal and vertical projections of these edges. The prerequisite of our method is the existence of intact search patterns and quiet zones around the QR code. The novelty of the method lies in the definition of the bounding box of the QR code, especially in the case of perspectively distorted QR codes, and in the handling of modules of variable size.

This method was validated on a test set of synthetic and real samples and compared with competitive solutions. Experimental results show that their method has a high detection rate. A QR code is only considered

successfully recognized if it is decoded, not just localized. Accurate localization is a necessary but not sufficient condition for successful decoding (Karrach *et al.* 2020).

Figure 3. a - Correct QR code, b - Skewed QR code, c, d - Perspective distorted QR code, e - Wrapped QR code



Source: Created by the authors

The use of computer-readable visual codes has become commonplace in our daily lives, in industrial environments and in private use. The process of reading visual codes consists of two tasks: localization and data decoding. Bodnár and Nyúl investigate the localization efficiency of cascade classifiers using Haar-like features, local binary patterns and histograms of oriented color transitions, which are trained on the search patterns of QR codes and the entire code region and propose improvements in the field of post-processing. Various cascade classifiers based on different features and training objectives are presented and their performance and QR code localization ability are studied. Their approach can be used in real-time applications with high confidence rates and moderate false positive rates, which can be tuned according to the requirements of each final application, mainly depending on the training parameters. Efficient automatic localization of visual codes is desirable in many industrial environments and in pre-user cases where localization is done with little human assistance. According to their experiments, cascade classifiers are a suitable option for QR code localization (Bodnár and Nyúl 2015).

3.4 Artificial Intelligence in QR Code Identification

QR code recognition often faces the challenges of uneven background fluctuations, improper illumination, and distortions due to improper imaging methods. This makes it difficult to identify QR codes, so artificial intelligence-based systems were created to deal with the problem (Udvaros *et al.* 2019). To improve the recognition rate of QR image codes, Huo *et al.* use an improved adaptive median filtering algorithm and a QR code distortion correction method based on neural networks. This combination of artificial intelligence algorithms can match the distorted QR image into the geometric deformation pattern, and QR code recognition is realized. Their research deals with two-dimensional code distortion, which has been a serious research question in existing software systems. The research results obtained after emphasizing the pre-processing stage of the image showed that a significant 14% improvement in the reading speed of the QR image code can be observed after processing with the system algorithm in the article. The applied artificial intelligence algorithm has a certain effect on improving the recognition rate of the two-dimensional code image (Huo *et al.* 2021).

Chou *et al.* propose an algorithm that localizes and segments two-dimensional QR codes. The localization involved a convolutional neural network capable of detecting partial QR codes. Then, image processing algorithms were implemented to segment the barcodes from the background. Their experimental results show that the proposed approach was highly effective for detecting QR codes with rotation and deformation (Chou *et al.* 2015).

4. Discussions

QR codes and NFC technologies open up new dimensions in tourism. These technologies enable faster, more efficient information flow and interactivity between tourists and service providers. For example, with the help of QR codes, tourists can easily access city maps, restaurant menus, or even historical information. And NFC technology simplifies the payment and entry processes, reducing queue time and improving the user experience.

Artificial intelligence plays an important role in this process. AI enables faster and more accurate recognition of QR codes, which increases the reliability of the data and the quality of the user experience. In addition, with the help of AI, applications using QR codes and NFC technology are able to provide personalized offers and information to tourists, further refining the experience.

These technologies are not only beneficial for tourists, but also for service providers. They enable more accurate feedback and data collection, which can serve as a basis for further development of services. The use of QR codes and NFC technologies thus contributes to increasing the competitiveness of the tourism sector and promoting digital transformation.

The research also highlights that technological development does not stop, and its application in tourism constantly brings new opportunities and challenges. The document draws attention to the fact that further research is essential in order to fully exploit the technological potential inherent in tourism. This creates an opportunity not only to improve the tourist experience, but also to promote sustainable tourism.

The research contributes to the expansion of scientific knowledge in the field of tourism and technology, showing how the use of QR codes and NFC technologies positively affects the experience and operation of both tourists and service providers.

Conclusions and Further Research

In recent years, the increase in the number of research related to the socio-economic sustainability of digitalization and tourism is causing an increasing interest in the topic. Research in the last decade has produced many empirical studies in this area. According to bibliometric analyses, the research focus was on ICT, especially AR and VR technologies, within the social and economic sustainability of tourism. We have presented how we can use the possibilities of ICT in tourism, how we can access useful information with the help of Quick Response (QR) codes.

A QR code is a two-dimensional matrix barcode that uses the ISO/IEC 18004:2006 (18004:2015) standard, designed by Denso-Wave Corporation of Japan in 1994. Its advantages are high-speed recognition and strong error correction capabilities. The QR code is generated based on the protocols described in the standard, the same protocols are used for decoding.

In our article, we mainly focused on identifying the more distorted QR codes. In this case, the recognition rate of the QR code is very low or cannot be recognized at all. Improving the recognition rate of the QR code in special circumstances is of great importance, and improving the recognition rate can greatly promote the use of QR codes. We have proposed several algorithms for recognizing and improving QR codes. A detailed analysis of the image pre-processing work of the QR code components is performed before the QR code is decoded, followed by an analysis and research of the current QR code image pre-processing methods.

The use of QR codes and NFC technologies in tourism offers many advantages. These technologies enable quick and easy access to information and services, improving the tourist experience. By increasing the availability of services, tourists can find their way around more easily and use the available options more efficiently. Artificial intelligence plays a key role in the effective application of these technologies, especially in the fast and accurate recognition and correction of QR codes. Future research should focus on the further development of technological innovations, the development of new methods to improve the tourist experience, and the promotion of sustainable tourism. Emphasizing the importance of further investigating practical applications and expanding research towards new technological trends and the changing needs of tourism.

In the article, we dealt with the integration of QR codes and NFC technologies in tourism. We highlighted the importance of these technologies in improving tourist experiences and service availability. The article discussed the technological basis, recognition methods and challenges related to the use of QR codes in tourism, emphasizing the role of artificial intelligence in improving the recognition and decoding of QR codes. We

presented the future research directions and the possible effects of QR codes on tourism, illustrating the growing role of digital technologies in this area. The article makes a significant contribution to the understanding of QR codes that can be effectively used in tourism, providing insight into the opportunities and challenges offered by the technologies.

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Credit Authorship Contribution Statement

József Udvaros: Conceptualization, Literature review, Methodology, Investigation, Data curation, Writing - original draft preparation, Writing - review and editing, Visualization, Project administration, and Supervision.
Norbert Forman: Conceptualization, Literature review and Data processing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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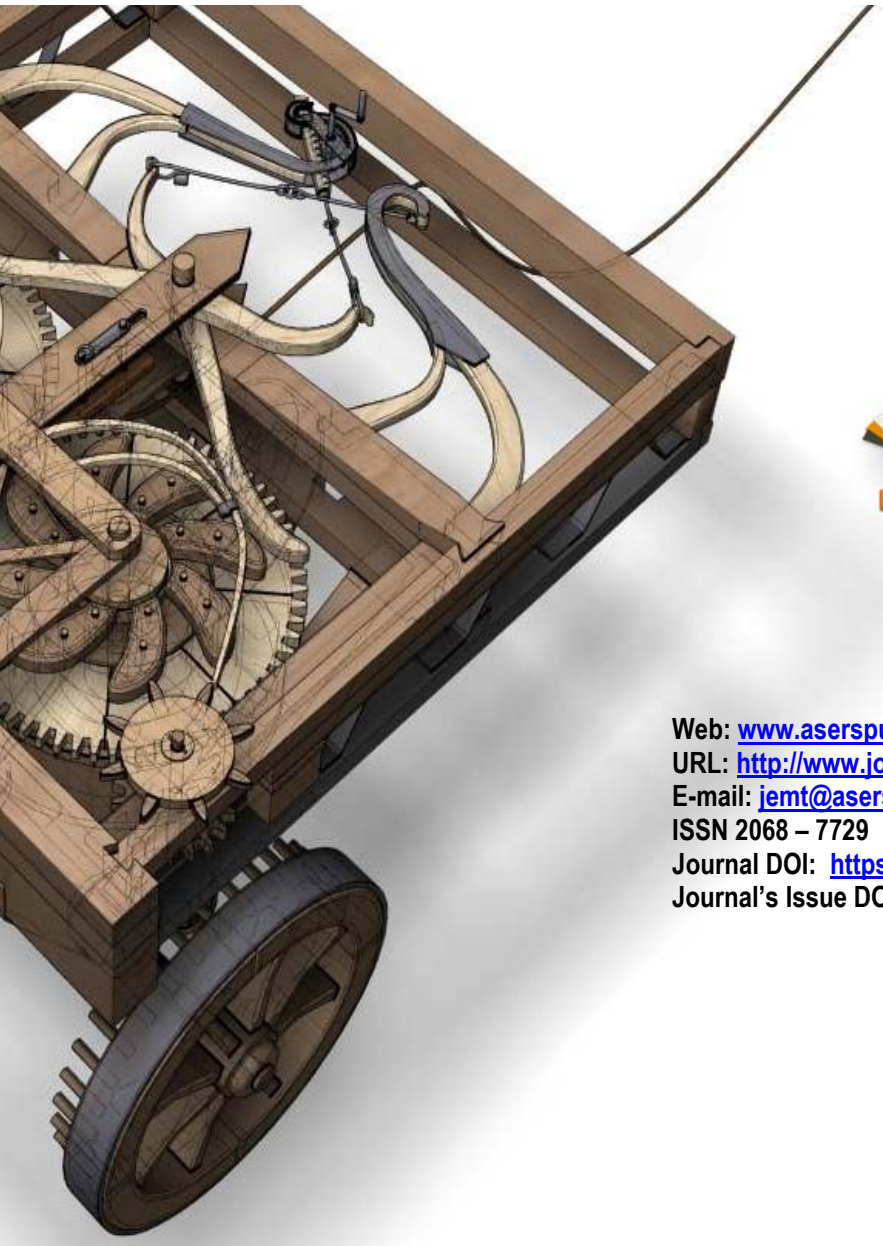

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