GLOBAL MEDIA AND CHINA
全球媒體與中國

Global Media and China
2023, Vol. 0(0) 1–19
© The Author(s) 2023
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/20594364231183618
journals.sagepub.com/home/gch
Sage

QR code: The global making of an infrastructural gateway

Gabriele de Seta
University of Bergen, Norway

Abstract

This article traces the history of machine-readable data encoding standards and argues that the QR code has become an *infrastructural gateway*. Through the analysis of patents, corporate documents and advertising, ethnographic observations, and interviews with professionals, I describe the global making of the QR code and argue that the convergence of data encoding standards, mobile computing, machine vision algorithms, and platform ecosystems has led to the emergence of a new component of computational infrastructures which functions as a gateway between different actors, systems, and practices. The central section of the article covers seven decades of machine-readable data encoding history across different national and regional contexts: from the invention and popularization of the barcode in the United States, through the QR code's invention in Japan and its success in East Asia, to its platformization in China. By revisiting this history through concepts drawn from the field of infrastructure studies, I argue that QR codes have become infrastructural gateways and conclude that this concept is useful not only to understand the current role of QR codes but also to identify and follow the emergence and change of other gateways in infrastructures to come.

Keywords

Barcodes, China, encoding, gateways, infrastructure, Japan, QR codes, standards

Encoded, standardized, machine-readable

I do not remember the first time I scanned a QR code, but it likely happened somewhere in East Asia. I bought my first smartphone in late 2012, and QR codes where quite a common sight in Hong

Corresponding author:
Gabriele de Seta, University of Bergen, LLE, Faculty of Humanities, Bergen 5020, Norway.
Email: notsaved@live.com

Kong, where I was living at the time. Notes from my fieldwork in China between 2014 and 2018 mention encounters with QR codes in various contexts [Figure 1]. In Shanghai, me and a local colleague discover that by scanning a QR code sticker on the restaurant table grants us a free milk tea worth 25 RMB—she quickly scans it and follows the restaurant's account on microblogging platform Sina Weibo, showing the result to the waitress, who shakes her hand explaining: "No, no, not on Weibo, you have to follow us on WeChat." A few days later, I subscribe to a paper magazine's WeChat account by scanning a QR code found in its pages. A couple of months later, I come across a CCTV13 news report about a new taxi-hailing app handing out promotional QR code stickers at train stations. In late 2015, I note how my Chinese friends have embraced the use of QR codes to share social media contacts or conduct small monetary transactions like sharing the cost of a night at the KTV. An advertisement poster in a Shanghai mall invites people to scan a QR code and follow its official WeChat account for a chance to win a designer bag. Scanning a QR code at a clothing store grants me a discount, and a friend paying after me quickly unfollows and re-follows their WeChat account to obtain the discount as well. Another friend who is organizing a concert collects ticket payments from audiences who scan a QR code displayed on her smartphone. In 2017, I land at the Shanghai Hongqiao airport and discover that my navigation app doesn't provide maps of China anymore—a large screen in the immigration hall encourages passengers to instead download and install Baidu Maps by scanning the QR code pointing to the appropriate app store.

In retrospect, all these occasional encounters with QR codes plot a precise trajectory in the global history of this machine-readable data encoding standard. In early 2023, 3 years into the COVID-19 pandemic, QR codes have become familiar to many people around the globe as contactless alternatives mediating multiple forms of social interaction: ordering food at a restaurant, boarding a plane, or certifying someone's vaccination status. But a decade before the convergence of pandemic governance and machine-readable encoding standards, QR codes were becoming popular in China, where—as the examples in the previous paragraph suggest—they afforded access to a variety of systems, services, products, and practices. And before that, QR codes had already been widely used

Figure 1. Advertisement for a Shanghai jewelry store using WeChat QR codes positioned inside mock-up smartphones, alongside remnants of another QR code on a ripped sticker. Photo by the author, October 2016.

for years in several East Asian countries, following the popularization of mobile devices capable of scanning and decoding them. This history leads to Japan, where the QR code was invented in 1994 and where it found its initial success beyond industrial applications, and points further back in time: as one among many varieties of 2-D encoding symbologies, the QR code resonates with several aspects of the invention and popularization of barcodes between the late 1940s and early 1970s. Despite its diminutive size and apparent simplicity, the QR code sits at the intersection of several domains of sociotechnical inquiry: it is a method of data encoding, an open technical standard, and a nexus of algorithmic calculation. The global history of the QR code, following its diffusion in Japan, throughout East Asia, to China and then the world, is a prime example of how an unassuming square matrix of encoded, standardized, machine-readable data can transcend its intended use and become a key component of informational infrastructures.

By analyzing the global making of a data encoding standard, this article argues that the QR code has become an *infrastructural gateway*. The concept of gateway has been extensively used in infrastructure studies to describe sociotechnical intermediaries that translate between networks or systems (Sandvig, 2013, p. 98). Through the analysis of patents, corporate documents and advertising, ethnographic observations, and interviews with professionals, I revisit the global history of the QR code and analyze how the convergence of data encoding standards, mobile computing, machine vision algorithms and platform ecosystems has led to the emergence of a new component of computational infrastructures which functions as a gateway between different systems, actors and practices. This history is global in scope, and yet the specific trajectories it followed in different national or regional contexts contributed in unique ways to the development of this infrastructural gateway. My analysis of the global making of QR codes responds to two recent proposals. The first is the call for regionalizing the analysis of media platforms and infrastructures beyond the U.S.-centric examples that are commonly projected onto the global (Steinberg & Li, 2017). The second is the invitation to expand the analysis of mobile media beyond smartphones and towards other technologies like portable music players, RFID tags, or barcodes, through the lens of infrastructure studies (Frith & Özkul, 2019). In the central section of the article, I revisit seven decades of machine-readable data encoding history across different national and regional contexts: from the invention and popularization of the barcode in the United States, through the QR code's invention in Japan and its success in East Asia, to its platformization in China. I then analyze this history through concepts developed in the field of infrastructure studies, theorizing how and why QR codes have become infrastructural gateways. Finally, the conclusion argues that the concept of infrastructural gateway is useful not only to understand the current role of QR codes but also to identify and follow the emergence and change of other gateways in infrastructures to come.

From bars to squares: Seven decades of encoding history

A QR code is a rather unassuming object: a square matrix of black and white blocks with larger black squares positioned in three of its corners, often only a few centimeters in size, it can be printed on paper, stickers, labels, and surfaces, or displayed on screens. To human users familiar with it, the code registers as an opportunity for some sort of interaction mediated by a digital device. To machine users capable of interpreting it, a QR code is a string of encoded data hidden among the pixels of a digital image, meant to be identified and decoded. In functional terms, a QR code is not so different from a barcode—it accompanies an object, location, or person; it can be scanned; and it contains some sort of data—only, instead of being composed of bars, it is made of square blocks. But what might superficially seem a modest technical advancement points towards several different implications of how data is encoded into machine-readable patterns. As Lucas D. Introna argues, encoding enframes countless aspects of contemporary mediation, and should be investigated as a key ontological category of digital culture (2011, p. 114). Data encoding techniques, particularly the ones used in machine-readable patterns like barcodes and QR codes, contribute to the ongoing "full-blown standardization of space" (Thrift, 2004, p. 175), a condition under which increasing numbers of objects exist only to send and receive information about their own position and addressability. The encoding of a string of data into a machine-readable pattern could not happen without advancements in optical technologies capable of scanning it, efforts towards the standardization of its parameters, developments in error correction and compression algorithms compensating for its materiality, and changes in the geography and topology of computational infrastructures. Starting from the barcode's invention in the late 1940s and ending with the hype around China's "codeconomy" of the early 2020s, this section demonstrates how these processes have been an integral part of seven decades of machine-readable encoding history.

Lines in the sand

The patent for barcodes was filed in the United States by mechanical engineering lecturer Joe Woodland and graduate student Bernard Silver in 1949. Woodland recalls how, as the two were working on ideas for automating the capture of product information at supermarket checkouts, he happened to be sitting on Miami Beach where, inspired by the Morse code he had learned as a Boy Scout, he poked some dots in the sand and then prolonged them into vertical bars by dragging his fingers (Weightman, 2015, p. 110). The barcode patent was granted in 1952, outlining Woodland and Silver's vision of a concentric pattern of lines that could be read from any angle: the first barcode was, in fact, round [Figure 2]. Unfortunately, Woodland and Silver's method to encode data in concentric bars of variable width was difficult to print accurately and still required a machine capable of decoding it: the prototype that the two engineers built was based on a 500-watt incandescent bulb and a oscilloscope, and was reportedly as large as a desk (Weightman, 2015, p. 110)—rather unwieldy for practical use at scale. The patent was sold and eventually expired until an advancement in optical technologies made it possible to read barcodes in a more reliable and convenient way: the invention of the laser in 1960. In the late 1960s, the intention to standardize supermarket retail resulted in the formation of an ad hoc U.S. committee dedicated to developing a Uniform Grocery Product Code. Woodland, working for IBM at the time, was involved in the company's bid, which would result in the Universal Product Code (UPC) still in use to this day. The Symbol Selection Committee drafted specifications for a barcode that contained a maximum of 10 digits, was easily printable, had a maximum footprint of 1.5 square inches, and could be quickly read by laser scanners from any direction with fewer than 1 in 20,000 undetected errors (Weightman, 2015, p. 124). It was another IBM engineer, George Laurer, who formalized the UPC barcode that the Symbol Selection Committee eventually accepted in 1973—his contribution was adding a checksum digit that could be used in error correction for smeared or damaged codes.

Standardization was an important first step: as the story goes, the first UPC barcode was scanned in 1974 by cashier Sharon Buchanan at the Marsh supermarket in Troy, Ohio. Among various grocery products, a pack of chewing gum was chosen to demonstrate how accurately the barcode reader could work even on items with a small packaging footprint. The commercialization of scanners drove the adoption of UPC barcodes, and a decade after the first demonstration, one third of supermarkets in the U.S. had installed scanners on their checkout counters (Basker, 2012, p. 1). Scanners progressively improved in accuracy and efficiency, speeding up the checkout process and reducing the cost of cashier labor, with scholars arguing that the broader information revolution happening around barcodes contributed to retail growth and an increase in product variety (p. 5).

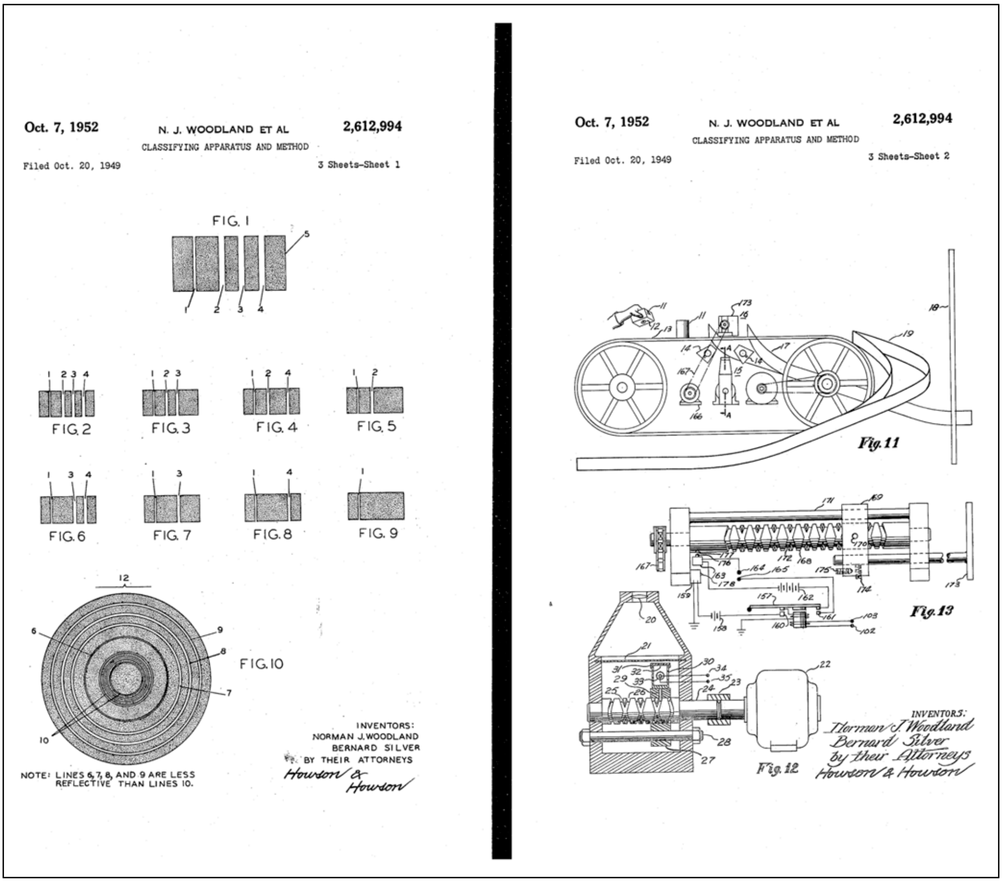

Figure 2. First two pages from Woodland and Silver's patent for a "Classifying apparatus and method" (1952), including schematics of the barcode and its reading apparatus.

Reflecting on the barcode as a new platform requiring "distributed investment, unequal economic burden, and uncertain profitability," Emek Basker notes how remarkable it was for barcodes to succeed as an infrastructural standard without government intervention and substantial subsidization (p. 24). Before successfully disappearing into the material backstage of retail infrastructure, barcodes had to surmount various barriers, including manufacturers' resistance towards printing codes on their products, the popular distrust of machine-readable codes as a replacement for human-readable prices, and the requirement of specialized in-store scanning equipment (Basker, 2012, pp. 23–24).

In their analysis of the "thinking market infrastructure" emerging from the interaction of barcodes, scanners, and computer systems, Hans Kjellberg and coauthors have mapped three partially overlapping phases of this process (2019). In the first phase, new technologies had to be developed and standardized while industry actors had to convince the public about their potential benefits (Kjellberg et al., 2019, p. 216). In the second phase, the nation-wide implementation of barcodes drove the standardization of larger information systems that allowed stores to improve logistics, delegate scanning from cashiers to customers, and even introduce new forms of retail marketing like coupons and loyalty cards (p. 219). In the third phase, after having become transparent and routinized, barcodes started to be reappropriated thanks to the emergence of unforeseen technological developments in optical sensors and mobile consumer devices capable of scanning them, which enabled competitors and third-party actors to build new services on top of the existing barcode infrastructure (p. 223). Thanks to the affordability of laser scanners and the advent of digital cameras, consumers could reclaim a degree of agency over the data encoded in barcodes. Devices like the Barcode Battler videogame console released in 1991 or the CueCat hyperlink scanner given away for free in 2000 exemplify how, once established, a market infrastructure can become a platform for experimentation, opening up an encoding standard to unforeseen use cases and practices.

By the turn of the century, barcodes had also become global—as Nigel Thrift argues, a "crucial element in the history of the new way of the world, one which remains largely untold" (2004, p. 183). Their widespread application across industries shaped the physical routines of factory workers, delivery drivers, cashiers, and many other occupations. Contributing to the emergence of new urban infrastructures, "bit structures" like the barcode played a key role in the synchronization and informatization of commercial logistics, management, and marketing (Hosoya & Schaefer, 2001, p. 158). In his ethnographic analysis of hypermarket cashiers in Spain, Oriol Barranco notes how new trainees interfacing with barcodes and scanners not only had to acquire new technical skills but also adopted new embodied dispositions and habits (2019). Consumers encountering foreign commodities across the globe learned to read UPC codes as indicators of product quality (Mandel, 2002, p. 220), and the informatization of barcode scanning allowed activists to organize targeted boycotts of products from specific countries (Eli et al., 2016). At the same time, the abstracted and repetitive pattern of barcodes had come to metaphorically represent submission to commercial logics and capitalist control (Elmer, 2003, p. 237). Oscar H. Gandy identified barcodes and barcode scanners, alongside cameras and listening devices, as central to the growing arsenal of instruments of the "surveillance society" (1989, p. 68), and it is not a coincidence that Philip Agre titled his essay arguing against facial recognition in public places "Your face is not a bar code" (2003). These fears were not only prophetic speculations about a globalized encoding standard: barcodes were a key component of the technopolitics of identity in apartheid South Africa, where they facilitated the computerization of population management through scannable biometric identification (Edwards & Hecht, 2010); barcode data became a key source of consumer predictions for marketers (Amoore, 2009, p. 22), and the use of barcodes and scanners in fulfillment center logistics has supported the implementation of extractive labor control systems (Staab & Nachtwey, 2016, p. 467).

A board game and a skyline

The encounter between the global success of barcodes and the development of increasingly complex networked computing systems resulted in growing demands for more capacious, compact, and reliable symbologies. The barcode's technical specifications were being pushed to their limit: while the UPC barcode was designed to encode only a few numeric digits, mono-dimensional symbologies like Code 39 and Code 128 expanded its content to longer strings of alphanumeric and full-ASCII character sets. But there was a material limit to the practicality of a horizontal sequence of bars. An important shift was introduced by Code 49, a variable-length symbology developed by David Allais in 1987, the first to expand the mono-dimensional pattern of the barcode into a two-dimensional, "stacked" one. Some of the early 2-D codes such as Code 49 or PDF417, developed by *Ynjiun P. Wang* in 1991, are still read through linear laser scanning which decodes them row by row,

Figure 3. Examples of 1-D and 2-D code symbolisms: UPC-A and Code-39 (top), PDF417, Data Matrix, Aztec, and MaxiCode (bottom).

tying their application to the availability of compatible scanners. It was the popularization of a relatively new optical technology—the digital image sensor—that prompted the next major development in data encoding patterns, with a new generation of 2-D symbologies like the Data Matrix or Aztec codes [Figure 3] capable of encoding exponentially more data in smaller footprints. The Data Matrix code was developed by Massachusetts-based company ID Matrix in 1987, and standardized in 1996; the Aztec code was invented by Andrew Longacre Jr. and Robert Hussey in 1995, and published by U.S. industry trade group AIM, Inc. in 1997. The history of the QR code begins around the same years on the other side of the Pacific, when in 1992 Japanese company Denso Wave tasks one of its engineers, Masahiro Hara, with developing a better alternative to 1-D barcodes.

In Japan, factories were demanding for a data encoding solution that could store more information and require less labor—barcodes could only store a few alphanumeric characters and could not encode Japanese *kana* or *kanji*, which resulted in individual items and components requiring multiple labels that had to be printed and scanned one by one (Fukuda, 2019). Denso Wave, a subsidiary of automotive components manufacturer DENSO corporation, had a decade of experience in manufacturing barcode scanners and developing barcode recognition, OCR, and voice recognition systems (Denso Wave, 2022); Hara himself was familiar with the limitations of barcodes, having worked on designing a barcode reader in the early 1980s (McCurry, 2020). In his search for a symbology that could encode more data, was faster to read and more resilient to damage than linear barcodes, Hara found inspiration in David Allais' Code 49 and improved it with a key intuition: rather than stacking horizontal rows of bars, his prototype utilized both vertical and horizontal axes (Goodrich, 2020), filling a two-dimensional space with square block modules dedicated to specific encoding functions. The origin story of the QR code is remarkably similar to the one of the barcode: while Woodman drew lines in the sand of Miami Beach, Hara was inspired by the board game *go*, which he used to play during lunch breaks. As he recalls, the arrangement of black and white pieces on the game board grid struck him as an efficient way of storing information (Fukuda, 2019). The "two-dimensional code" that Hara and colleagues described in the patent filed in 1994 shares the concept of a grid matrix structure with other 2-D encodings being developed around the same years such as the Data Matrix and Aztec codes.

In terms of technical specifications, the main area of the QR code's square matrix contains the string of data stored in the symbol, alongside version, format, and error correction information, as well as a timing pattern—all encoded as individual black and white blocks masked through one

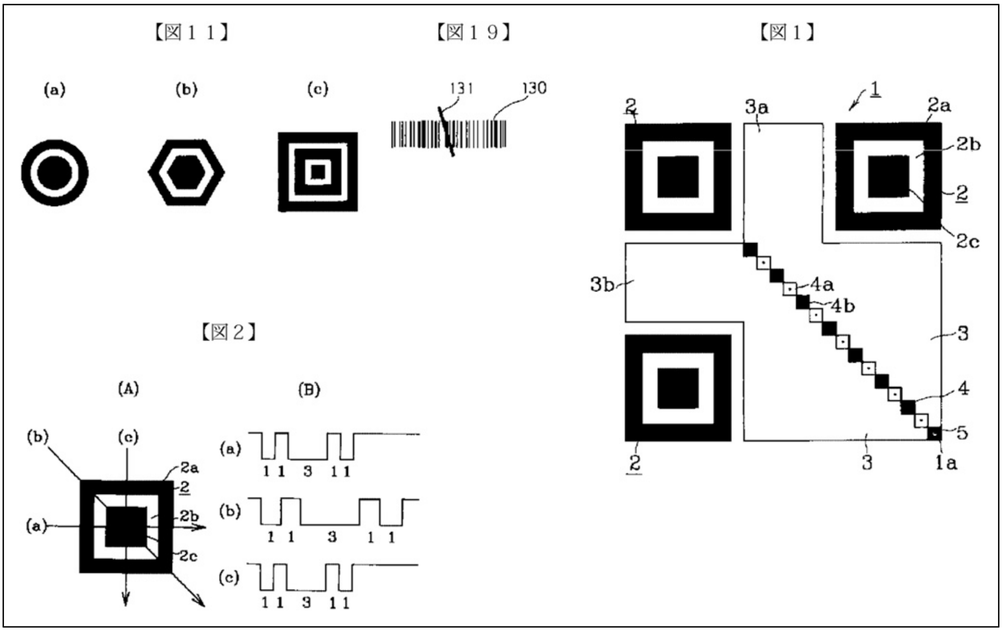

Figure 4. Illustrations from the "Two-dimensional code" patent (Hara et al., 1999) detailing shapes and positioning of the finder pattern around the main data area, as well as examples of how the 1:1:3:1:1 ratio remains constant across scanning orientations vis-à-vis the horizontal scanning of one-dimensional barcodes.

among eight regular patterns designed to avoid generating large areas of the same color. To compensate for partial damage to the pattern, Masahiro Hara chose to use Reed-Solomon codes, a forward error correction method based on the oversampling of a polynomial derived from the encoded data which is also used by the Data Matrix code as well as by several digital media such as MiniDiscs, CDs, and DVDs. When generating a QR code, users can select four different correction levels (7%, 15%, 25%, and 30%) depending on the amount of expected damage that might render parts of the code illegible. Hara's patent also details what is perhaps the key original innovation of the QR code: a pattern of three black squares in concentric black and white frames, positioned at the two top and bottom left corners of the code [Figure 4]. Thanks to their positioning and design, the squares composing this "finder pattern" can be easily identified from any scanning direction (Hara et al., 1999). In a TV interview, Masahiro Hara recalled how the view of the Tokyo skyline from an early morning train ride gave him the inspiration to solve the scanning orientation problem—just like people looked at tall buildings to orient themselves in a city, scanners needed a "special symbol" standing out from the surrounding pattern (Goodrich, 2020). Hara and his team conducted an extensive survey of Japanese printed matter in order to find the least common ratio of black and white areas, deriving the 1:1:3:1:1 proportion that characterizes the QR code's iconic finder pattern (Denso Wave, 2022).

Hara and colleagues were granted patents for their two-dimensional code in 1998 (EU), 1999 (Japan), and 2000 (US). Denso Wave branded the symbology as "QR Code" (from Quick Response), emphasizing one of its key features: speed. Besides being capable of storing around 7000 characters including Japanese *kanji* and being resistant to dirt and damage, the QR code could be read at "ten times the speed of other codes" (Denso Wave, 2022). The QR code was also approved as an AIMI (Automatic Identification Manufacturers International) standard in 1997, JIS (Japanese Industrial Standard) in 1999, and ISO international standard in 2000 (Denso Wave, 2013b). At the time of writing, Denso Wave holds numerous patents related to QR codes, including ones detailing the functioning of scanning devices and of proprietary versions of the code, but has since the beginning waived its rights on the original patent and allowed the third-party use of QR codes as long as it follows the relevant standards (Denso Wave, 2013a). Masahiro Hara explains this decision in terms of both corporate business model and personal professional preference:

> Our business model for the QR code was to have as many people as possible using it, and to make profits from reading devices and systems, which are our strengths. In order to achieve this, it was relatively easy for us to decide to abandon our patent rights and to promote the QR code. This stance has not changed even today. As a developer, I decided to abandon patent rights partly because I had developed a good product and wanted everyone to be able to use it freely. (Interview with the author, December 2021)

Making a patented symbology public domain as an open standard is not an uncommon choice for machine-readable codes—AIM, for example, released the Aztec code as public domain as soon as it was patented in 1997. But as the following sections will illustrate, this decision would be key in paving the circuitous routes which brought the QR code from a manufacturing logistics solution to a key component of global infrastructures that is today recognized as an IEEE Milestone (Denso, 2020).

Mobile portals

The 2-D barcode developed by Masahiro Hara and colleagues found the success that Denso Wave hoped for: Japanese manufacturers adopted the QR code to label items more conveniently and manage logistics more efficiently. But the unassuming matrix of black and white squares also quickly found its way into Japanese everyday life in ways that pleasingly surprised its creator. In the early 2000s, Hara recalls, he started seeing QR codes on betting slips discarded on the streets (McCurry, 2020). Shortly after, an unforeseen development in optical technologies became once again the catalyst for the popularization of a data encoding standard: camera phones. As Hara explains, the QR code was designed before smartphones and camera phones existed, and at its launch nobody imagined that cellular phones would be one day able to take photos: "At the time, the general public imagined a world where QR codes could be read with a digital camera. […] It was only in 2002 that the first QR code could be read by a cell phone" (Interview with the author, December 2021). This mobile phone was the Sharp J-SH09, released in August 2002 by Japanese carrier J-phone; other carriers like DoCoMo and Vodafone started offering mobile phones with QR code scanning capabilities shortly after (Kato & Tan, 2005, p. 2). The encounter between these two mobile technologies—camera phones and QR codes—triggered a burst of third-party experimentation, much like the availability of laser scanners opened up the use of UPC barcodes to the public. By the mid-2000s, in Japan, the QR code coexisted with dozens of other 2-D symbologies, and while a comparative study predicted that a competitor (the VS Code) might have the best chance to emerge as a mobile phone data encoding standard (Kato & Tan, 2005, p. 7), just 2 years later, the same authors acknowledge that the QR code had successfully become "the de facto standard for many mobile companies and advertising departments in Japan" (Kato & Tan, 2007, p. 76).

In the early years of QR code use in Japan, which coincided with the country's pivot to mobile telephony and internet access, the most common application was that of linking users to online information in a more convenient way—bypassing the inconvenience of typing URLs on a mobile phone keyboard (Dou & Li, 2008, p. 61). Similar experiments were implemented in other parts of the world: as a report from Singapore documents, by the late 2000s QR codes were used in Australia to manage blood testing processes and tracing livestock, in China and France to certify jewelry, and in Taiwan for e-business and managing payment slips (Soon, 2008). The arrival of smartphones, equipped with more powerful camera sensors and better screens, further cemented the status of QR codes as the global standard for the visual encoding of machine-readable information, and propelled their use in domains beyond logistics, such as advertising and information. As a marketing book published in the U.S. suggests with enthusiastic tones,

> it doesn't really matter how it works, why it works, or what the technology is behind it. The simple fact is that millions of dollars have been spent perfecting the technology, and millions more have been spent creating these codes as a marketing standard throughout Asia and now Europe. Currently, in countries such as Japan and South Korea, and now emerging throughout Europe and the Middle East, QR codes are becoming more and more the standard way of communicating with potential clients through print media. (Weir, 2010, pp. 11–12)

Despite the global excitement around QR codes for advertising, marketing, and communication, their adoption was geographically uneven: fashion company Ralph Lauren pioneered their use in 2008 by partnering with the US Open tennis championship, and other companies used QR codes to connect users to mobile app stores (Okazaki et al., 2012, p. 104), but the standard gained less traction in Europe or North America than in East Asian countries, where it became commonly used as a bridge between offline products or advertisement and online content or loyalty programs (Cata et al., 2013), or as an "analog portal" (Baik, 2012) to digital information.

In East Asia, the creation of an infrastructure for QR codes was deemed to be essential for their success as analog portals. This infrastructure would require not only the large-scale uptake of QR codes in public and private spaces but also the availability of scanning hardware and software (Baik, 2012, p. 431). A wealth of computer science research was dedicated to optimizing the scanning capabilities of camera phones by, for example, recovering QR codes from illegible photos (Sun et al., 2007), decoding them with dedicated software (Yue Liu et al., 2008), or identifying them with image processing algorithms (Gu & Zhang, 2011). These advancements would prove to be essential for the next step in the global history of QR codes: their platformization. By the early 2010s, the convergence of smartphones, mobile internet access, and social media apps allowed users to interact with them without the need for dedicated hardware or software. Multiple app-based platforms experimented with the use of QR codes for social networking purposes—not just to facilitate the scanning of codes encountered by users on printed matter or urban surfaces but also to generate and display personalized codes linking to one's contact details or verifying user identification. For example, between 2010 and 2011 both Japanese messaging app LINE and South Korean one KakaoTalk introduced the possibility of logging in and adding new contacts by scanning a QR code [Figure 5]. In a reflection on the development of his encoding standard written for its twenty-fifth anniversary, Masahiro Hara identifies the integration of QR codes into social networking platforms and smartphones apps as the inflection point that propelled them beyond the domains of manufacturing, distribution, and public service, and towards a consumer market increasingly oriented by O2O (online-to-offline, or vice-versa) business strategies (Hara, 2019, p. 26).

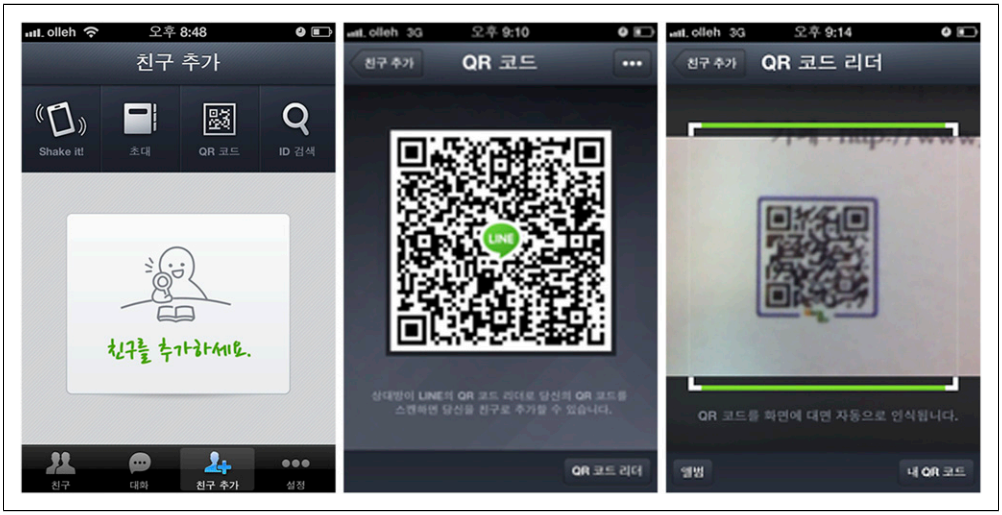

Figure 5. Screenshots from a South Korean blog post explaining how to add LINE contacts via QR code: selecting the new function among four options, displaying one's QR code, or scanning someone else's code (Hot Chilli, 2011).

An entrance to platforms

Throughout the 2010s, the adoption of the QR code by Chinese tech companies has played a key role in its global trajectory. The QR code standard was formalized into a Chinese National Standard (GB/T 18,284) as early as 2000 (Soon, 2008, p. 68), and the Chinese term for QR code, 二维码 [*erweima,* "two-dimensional code"] is clearly patterned on the original name that Masahiro Hara and colleagues filed their patent under. For more than a decade, the QR code did not find particular success in China. In 2011, Alibaba launched a mobile app for its digital payment system Alipay, which offered the option of scanning QR codes to process transactions. In the same year, inspired by the popularity of chat apps like Kik Messenger, Shenzhen-based internet company Tencent launched a new smartphone app called WeChat. Despite Tencent's experience in developing messaging tools, WeChat struggled to attract users, and the company started experimenting with new features oriented towards facilitating social contact. In December 2011, version 3.5 of WeChat introduced a new social feature: the possibility for users to generate a personal QR code linking to their account, and to add new contacts by scanning their own QR code (Shimota, 2022, p. 77). This function quickly caught on with users and contributed to the app's adoption: as I consistently observed while on fieldwork, asking new acquaintances "你扫我还是我扫你?" [*ni sao wo haishi wo sao ni*? "Do you scan me, or do I scan you?"] had become a common catchphrase when adding someone on WeChat. The combination of high-resolution smartphone screen and camera allowed users to bypass exchanging phone numbers or account names by simply displaying and scanning a QR code, all within the same app. On May 23, 2012, WeChat founder Allen Zhang (who is today Senior Vice President of Tencent) explained his vision behind the introduction of QR codes in an oft-quoted WeChat post:

> The entrance to the PC internet is in the search bar. The entrance to the mobile internet is in the QR code.

Allen Zhang's use of the term 入口 [*rukou*, "entrance"] is in line with the "analog portal" imaginary of the early 2010s, and reflects the massive shift from personal computing and broadband internet to smartphones and mobile internet that was reshaping China's digital ecosystem around the same years. The success of QR codes as social contact portals introduced WeChat users to this encoding standard, cementing the connection between the app and the code-scanning camera function. Over the following 2 years, WeChat expanded the range of features that made use of QR codes, including the possibility of subscribing to public accounts, setting up group chats or opening links in the app's web browser. The feature that propelled the QR code beyond smartphone screens and onto physical surfaces was introduced in 2013: WeChat Pay, a digital wallet which included the QR code as one of its money transfer modalities. The success of large-scale promotional campaigns in collaboration with other apps and TV programs convinced millions of users to link their bank accounts to WeChat and take advantage of this new and convenient way to conduct small purchases or private transactions (Plantin & de Seta, 2019, p. 265). Stores and stalls throughout China started displaying QR codes on their counters, allowing customers to pay with WeChat Pay or other digital wallets (such as Alibaba's Alipay, Tencent's main competitor) which quickly became "the automatic, reflexive interface for […] the movement of money" (Brunton, 2018, p. 186). In the words of Kevin Shimota, former Global Head of Partnerships and *Marketing for WeChat, if* QR codes initially replaced business cards, facilitating the exchange of contact details between individuals, their integration in WeChat Pay offered an alternative to credit cards, mediating between consumers and commercial actors (interview with the author, December 2022).

By the second half of the 2010s, the QR code was adopted as a key component by countless apps and services, and had become a pervasive feature of everyday life in China (Greenspan, 2021, p. 207), facilitating user interactions with social media platforms, payment systems, customer memberships, food delivery, transportation, and much more (Jiang, 2019). In sum, the QR code became an entrance to platforms, a familiar entry point for users to access a wide variety of services. Despite its global uptake as an open standard that facilitated its platformization, companies like Tencent and Alibaba tried to develop their own proprietary symbologies with mixed results, and are eager to take credit for the success of the QR code in China. A revealing example of this corporate capture of QR codes are two reports released by Tencent in January and May 2020. In the first report, the company identifies the rise of the "codeconomy" [码上经济 *mashang jingji*], a new economic model enabled by the QR code's function as a "connector between things, people, and services" (Institute for Global Industry, Tsinghua University et al., 2020). In the codeconomy, QR codes become "online entrances for retail stores," help small merchants to manage transactions, and facilitate the provision of government services. The second report, published at the onset of the COVID-19 pandemic, emphasizes how this connection between physical and digital worlds can contribute to epidemic governance while also supporting China's lockdown economy (WeChat et al., 2020, p. 9). In Tencent's corporate theorization of the codeconomy [Figure 6], QR codes facilitate the convergence of the "four-flows-in-one" of people, information, businesses, and capital (p. 13), and the centralization of an entire platform ecosystem around this new "value connector" allows WeChat to "stimulate the demand for value of new infrastructure layer by layer" (p. 16).

The QR code as infrastructural gateway

The seven decades of history revisited in the previous sections trace the global making of a data encoding standard from the popularization of barcodes and the invention of the QR code in Japan to its adoption across East Asia and its platformization in China. Following unpredictable sociotechnical trajectories and steered by countless commercial and institutional actors, the QR code has

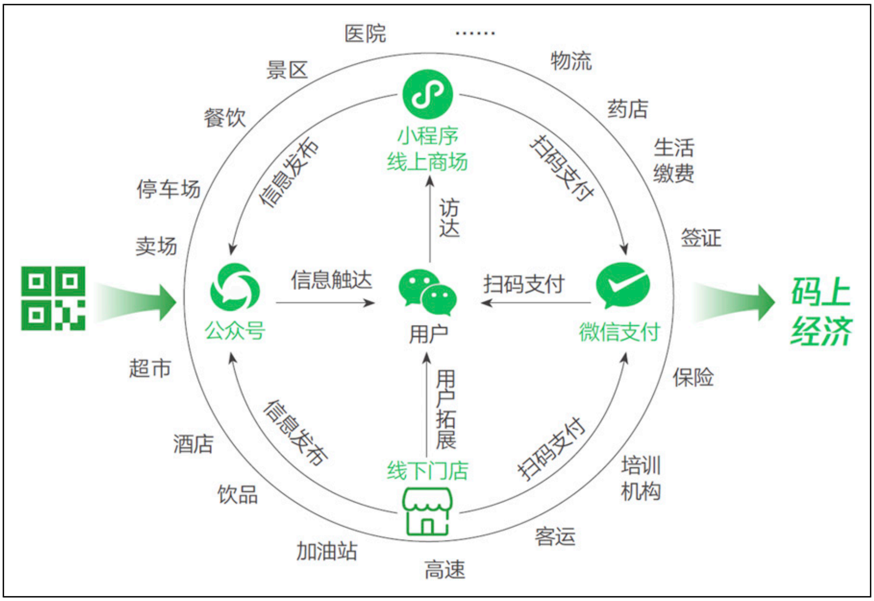

Figure 6. Diagram of the "codeconomy" [码上经济 *mashang jingji*] according to Tencent (WeChat et al., 2020). QR codes (left) function as an entry point to the platform ecosystem, allowing the WeChat user (center) to conduct monetary transactions and circulate information across physical stores, public accounts, e-commerce platforms, and the WeChat Pay wallet, leading to a codeconomy (right).

gone from being designed as an industry-specific barcode replacement to becoming an integral component in digital infrastructure-building. Four interleaved threads are woven throughout this history: First, the increasing relevance of data encoding in modernity, evidenced by the profound economic impact of machine-readable patterns on consumption and logistics; second, the symbiotic relationship between encoding symbologies and innovations in optical technologies such as laser scanners or digital image sensors; third, the importance of standardization for third-party adoption, which was pivotal in making both barcodes and QR codes global; and fourth, the central role that encoding plays in computational infrastructures, as exemplified by the QR code's contribution to platformization. These threads share a common kernel: the work of articulation between objects, technologies, actors, and systems. Machine-readable data encoding standards enable countless kinds of transactions through "new means of addressing the world" (Thrift, 2004, p. 182). They are peculiar infrastructural components that need to remain visible and hence shape the experience of both space (Dourish & Bell, 2007, p. 417) and time, as "encoding *translates* agency (becoming) from one event to another, thereby *extending* the agency/becoming of actors beyond the boundaries of the singular local event" (Introna, 2011, p. 117). Building on these theoretical insights, how can the history of a data encoding standard help theorize the work of articulation in informational infrastructures? The argument advanced in this section is that QR codes have become infrastructural gateways, a key element in the articulation of digital infrastructure.

In the field of infrastructure studies, encoding and standardization have been widely discussed as key components of articulation work, particularly in terms of how practices of ordering and classification have defined modernity (Bowker & Star, 1999). The concept of "gateway" has been used to explain how locally-bound and heterogeneous systems become connected into networks

(Edwards et al., 2007, p. 7). Examples of gateways include AC/DC power converters, the ISO freight container, coding languages, and file formats (p. 10), and succeed by not prescribing a preferred usage:

> Neither the exact implementation of standards, nor their integration into local communities of practice, can ever be wholly anticipated. For this reason, gateways in information infrastructures work best when they interlock with the existing framework "below the level of the work," i.e. without specifying exactly work is to be done or exactly how information is to be processed. (pp. 16–17)

Gateways like the UPC barcode allow multiple systems—industrial production, logistics, and retail—to become integrated, with users and third-party actors taking charge of furthering their interoperability (Edwards et al., 2009, p. 367). The standardization of gateways—from dedicated ones like the AC/DC converter to generic ones like Java and meta-generic ones like the OSI model—does not necessarily lead to the entrenchment of systems but can contribute to their flexibility (Egyedi, 2001). For example, the transition between 1-D and 2-D data encoding symbologies was made possible by the successful integration of barcodes and scanners in market infrastructures, since the increase in compatibility between systems facilitates the shift to new standards (Egyedi & Spirco, 2011, p. 949). Barcodes have been consistently theorized as "underlying structures" connecting informational systems (Hosoya & Schaefer, 2001) or as links between material objects and their virtual representation (Kitchin & Dodge, 2014), recognizing their role in infrastructure-building by articulating heterogeneous systems from a level below specific uses.

The invention of the QR code by Masahiro Hara and colleagues in 1994 resonates with several aspects of Woodland and Silver's invention of the barcode in 1949. Originally developed as a narrow solution to an industry need, the QR code was not conceived as a generic gateway for infrastructure-building; rather, it was designed as a dedicated gateway articulating specific systems in automotive manufacturing—a logistical intermediary (Nguyen, 2022). In less than two decades, thanks to its release as an open standard, the QR code was adopted, first in Japan and then throughout East Asia, in ways that clearly mark a shift towards general-purpose articulation: as an "analog portal" and "ambient media gate to the digital world" (Baik, 2012, p. 5), and as "links of bridges between static and dynamic media" (Fortunati, 2014, p. 62). The widespread availability of digital image sensors in mobile phone and then smartphone cameras, combined with the rise of platform companies, laid the groundwork for a process that, starting from East Asian countries, turned the QR code into a meta-generic gateway to digital infrastructures (Stevens, 2019, p. 86). The case of a app like WeChat is exemplary because it demonstrates not only the flexibility of QR codes as links and connectors but also their role in supporting processes of infrastructuralization: the QR code, particularly through its integration in WeChat Pay, becomes an meta-generic gateway, facilitating the provision of services by connecting systems to a centralized platform (Plantin & de Seta, 2019, p. 266). As digital infrastructures overlap and intersect into computational stacks, infrastructural gateways like the QR code create shortcuts between different layers and actors, allowing new topological configurations of previously unconnected systems and networks (de Seta, 2021, p. 2680).

What does this history say about the making of infrastructural gateways? To conclude, I identify four features of this process: it is *gradual*, *unplanned*, *situated*, and *opportunistic*. The *gradual* nature of how infrastructural gateways develop is evident how sociotechnical change shapes every step of the process: the progressive standardization of UPC barcodes and QR codes contributed to their success by allowing them to become part of logistical and market infrastructures as dedicated gateways (Egyedi & Spirco, 2011, p. 957). As machine-readable encoding patterns, QR codes could be more widely used as generic gateways only once digital image sensors capable of decoding them became accessible in portable networked devices such as mobile phones and smartphones (Kaminska, 2018). Their integration in digital platforms allowed QR codes to not only link physical to virtual or online-to-offline, but to support and articulate processes of infrastructuralization that consolidate layered stacks of devices, platforms, systems, and networks. Like barcodes, QR codes were not originally designed to become components of global information infrastructures: their success as infrastructural gateways was largely *unplanned* and contingent on unpredictable sociotechnical convergences. Every step of this gradual historical process has been *situated* in specific national or regional contexts, scaling up "entire infrastructural systems out of situated local needs" (Edwards et al., 2009, p. 370): barcode standardization has shaped the U.S. market economy; the machine-readability of QR codes has enhanced the efficiency of Japanese manufacturing logistics; their uptake as analog portals was made possible by the rapid informatization of East Asian countries; their consolidation as meta-generic gateway was catalyzed by the infrastructuralization of Chinese digital platforms. Lastly, the emergence of QR codes as infrastructural gateways was *opportunistic*, as they occupied a niche that competing gateways were not flexible enough to cover: through services like Alipay and WeChat Pay, QR codes took on the role of debit and credit cards, which had never achieved the same success as a gateway in China as they did in 20th-century America (Lauer, 2020, p. 11).

New gateways, new infrastructures

This article revisited seven decades of history of graphical data encoding standards, beginning from the invention of barcodes in the late 1940s U.S. and ending with the QR code's platformization in late 2010s China. By tracing the global trajectories of encoding standards, this history contributes to the regionalization of infrastructure studies by opening up bipolar tech narratives to broader developments in East Asia and beyond (Steinberg, 2020, p. 8); by centering the QR code's role as a gateway, my analysis expands the study of mobile media to a key component of digital infrastructure (Frith & Özkul, 2019). As infrastructure studies scholars have demonstrated, infrastructural development is characterized by both contingency and continuity, requiring the comparative study of situated histories and emergent patterns (Edwards et al., 2007, p. 1). My analysis of the making of QR codes as infrastructural gateways identified both continuities and contingencies: the *gradual* development of dedicated gateways into meta-generic ones and the *unplanned* nature of these trajectories are historical patterns that recur across different encoding standards and regional contexts. Conversely, the *situated* and *opportunistic* circumstances contributing to an infrastructural gateway's success point towards local specificities that can only be highlighted through comparison. The concept of gateway has proven to be central for the study of infrastructure and has become even more relevant with the consolidation of digital infrastructures like the internet, to the point that the analysis of infrastructural gateways can reveal a lot about large technical systems (Sandvig, 2013, pp. 98–99). Arguing that the QR code has become an infrastructural gateway is a provisional conclusion—as analyses of other gateways like RFID chips have demonstrated, these infrastructural components are in a constant state of "co-existence, convergence, and hybridization" (Schmidt et al., 2013, p. 112), and future infrastructures are likely to gradually and unpredictably develop around gateways that opportunistically respond to local needs.

The historical analysis outlined in this article stops at the beginning of 2020, when a Chinese platform company outlines its corporate vision of a "codeconomy" contributing to the Chinese state's push for the development of New Infrastructure. Starting from mid-2020, the COVID-19 pandemic has opened a new chapter in the global history of QR codes: Chinese companies like Alibaba and Tencent have relied on their experience with this infrastructural gateway and competed to repurpose it into a solution for pandemic governance, launching platform-based versions of the QR code designed to encode travel history, infection, and vaccination status, or venue access. Chinese authorities have sought to standardize these solutions into a national Health Code [健康码 *jiankangma*] which has been hailed as a key technological development for the country's pandemic response and has dramatically shaped everyday life in China for nearly 3 years (Zou & Di, this issue). As of early 2023, the Chinese government has abruptly stopped the use of Health Codes; in the meantime, QR codes have become a common sight across the globe, mainly through their integration in pandemic mitigation and governance measures such as vaccine passes and contactless service interfaces. Ironically enough, this sociotechnical moment resonates with the development of early transportation infrastructures and epidemic classification schemes, which resulted in one of the first gateways: the "clean bill of health" developed to track quarantined ships traveling back to Europe from Mecca by the end of the 19th century (Bowker & Star, 1999, pp. 17–18). From the barcodes used in apartheid South Africa's green passbooks (Edwards & Hecht, 2010) to the QR codes used in China's pandemic governance (Tai et al., 2021), the history of infrastructural gateways proves that their future is constantly in the making, and demands comparative analyses of their gradual and unplanned development in situated and opportunistic circumstances.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This research is supported by the *Machine Vision in Everyday Life* project, which has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme [grant number 771800].

ORCID iD

Gabriele de Seta https://orcid.org/0000-0003-0497-2811

References

Agre, P. E. (2003, September 10). *Your face is not a bar code: Arguments against automatic face recognition in public places*. UCLA. https://pages.gseis.ucla.edu/faculty/agre/bar-code.html

Amoore, L. (2009). Lines of sight: On the visualization of unknown futures. *Citizenship Studies*, *13*(1), 17–30. https://doi.org/10.1080/13621020802586628

Baik, S. (2012). Rethinking QR code: Analog portal to digital world. *Multimedia Tools and Applications*, *58*(2), 427–434. https://doi.org/10.1007/s11042-010-0686-9

Barranco, O. (2019). Barcodes, motricity and aesthetics. The embodiment of cashier work. *Revista Española de Sociología*, *28*(3), 99–117. https://doi.org/10.22325/fes/res.2019.40

Basker, E. (2012). Raising the barcode scanner: Technology and productivity in the retail sector. *American Economic Journal: Applied Economics*, *4*(3), 1–28. https://doi.org/10.1257/app.4.3.1

Bowker, G. C., & Star, S. L. (1999). *Sorting things out: Classification and its consequences*. The MIT Press.

Brunton, F. (2018). WeChat: Messaging apps and new social currency transaction tools. In J. W. Morris & S. Murray (Eds.), *Appified: Culture in the age of apps* (pp. 179–187). University of Michigan Press.

Cata, T., Patel, P. S., & Sakaguchi, T. (2013). QR code: A new opportunity for effective mobile marketing. *Journal of Mobile Technologies, Knowledge and Society*, *2013*(2013), 1–7. https://doi.org/10.5171/2013.748267

de Seta, G. (2021). Gateways, sieves, and domes: On the infrastructural topology of the Chinese stack. *International Journal of Communication*, *15*, 2669–2692.

Denso. (2020, July 10). *DENSO receives IEEE Milestone for QR code*. Denso. http://www.denso.com/global/en/news/newsroom/2020/201007-g01

Denso Wave (2013a). About the patent*. QR Code.Com*. https://www.qrcode.com/en/patent.html

Denso Wave (2013b). QR code standardization*. QR Code.Com*. https://www.qrcode.com/en/about/standards.html

Denso Wave (2022). QR Code development story. *Denso Wave*. https://www.denso-wave.com/en/technology/vol1.html?utm_source=pocket_saves

Dou, X., & Li, H. (2008). Creative use of QR codes in consumer communication. *International Journal of Mobile Marketing*, *3*(2), 61–67.

Dourish, P., & Bell, G. (2007). The infrastructure of experience and the experience of infrastructure: Meaning and structure in everyday encounters with space. *Environment and Planning B: Planning and Design*, *34*(3), 414–430. https://doi.org/10.1068/b32035t

Edwards, P. N., Bowker, G. C., Jackson, S. J., & Williams, R. (2009). Introduction: An agenda for infrastructure studies. *Journal of the Association for Information Systems*, *10*(5), 364–374. https://doi.org/10.17705/1jais.00200

Edwards, P. N., & Hecht, G. (2010). History and the technopolitics of identity: The case of apartheid South Africa. *Journal of Southern African Studies*, *36*(3), 619–639. https://doi.org/10.1080/03057070.2010.507568

Edwards, P. N., Jackson, S. J., Bowker, G. C., & Knobel, C. (2007). Understanding infrastructure: Dynamics, tensions, and design. In *[Report of a Workshop on "History & Theory of Infrastructure: Lessons for New Scientific Cyberinfrastructures"]* (p. 50). University of Michigan.

Egyedi, T. (2001). Infrastructure flexibility created by standardized gateways: The cases of XML and the ISO container. *Knowledge, Technology & Policy*, *14*(3), 41–54. https://doi.org/10.1007/s12130-001-1015-4

Egyedi, T., & Spirco, J. (2011). Standards in transitions: Catalyzing infrastructure change. *Futures*, *43*(9), 947–960. https://doi.org/10.1016/j.futures.2011.06.004

Eli, K., Dolan, C., Schneider, T., & Ulijaszek, S. (2016). Mobile activism, material imaginings, and the ethics of the edible: Framing political engagement through the Buycott app. *Geoforum*, *74*, 63–73. https://doi.org/10.1016/j.geoforum.2016.04.002.

Elmer, G. (2003). A diagram of panoptic surveillance. *New Media & Society*, *5*(2), 231–247.

Fortunati, L. (2014). The new frontiers of mobile media: Theoretical insights on their possible developments. In J. E. Katz (Ed.), *Living inside mobile social information* (pp. 57–75). Greyden Press.

Frith, J., & Özkul, D. (2019). Mobile media beyond mobile phones. *Mobile Media & Communication*, *7*(3), 293–302. https://doi.org/10.1177/2050157919850405

Fukuda, Y. (2019, December 14). *Hinto wa kyūkei-chū no "igo" datta... 'QR kōdo' kaihatsu hiwa uminooya ga akasu 'tokkyo ōpun ni shita' wake [The hint was a game of "go" during a break... The secret story behind the development of the "QR code", creator reveals the reason for making the patent "open"]*. Fuji News Network. https://www.fnn.jp/articles/-/16403

Gandy, O. H. Jr. (1989). The surveillance society: Information technology and bureaucratic social control. *Journal of Communication*, *39*(3), 61–76. https://doi.org/10.1111/j.1460-2466.1989.tb01040.x

Goodrich, J. (2020, November 13). *How a board game and skyscrapers inspired the development of the QR code*. IEEE Spectrum. https://spectrum.ieee.org/how-a-board-game-and-skyscrapers-inspired-the-development-of-the-qr-code

Greenspan, A. (2021). QR codes and the sentient city. *Studia Neophilologica*, *93*(2), 206–218. https://doi.org/10.1080/00393274.2021.1916993

Gu, Y., & Zhang, W. (2011). QR code recognition based on image processing. *International Conference on Information Science and Technology*, Nanjing, China, 733–736. https://doi.org/10.1109/ICIST.2011.5765349.

Hara, M. (2019). Development and popularization of QR code. *Synthesiology*, *12*(1), 19–28.

Hara, M., Watabe, M., Nojiri, T., Nagaya, T., & Uchiyama, Y. (1999). *Two-dimensional code (patent No. JP2938338B2)*. https://patents.google.com/patent/JP2938338B2/en

Hosoya, H., & Schaefer, M. (2001). Bit structures. In C. J. Chung, J. Inaba, R. Koolhaas, & S. T. Leon (Eds.), *Project on the city 2: Harvard Design School guide to shopping* (pp. 156–163).

Hot Chilli (2011, September 2). *Neibeo LINE aeb sayonghugi—Kakaotog VS LINE [Naver LINE app review—KakaoTalk VS LINE] [Naver Blog]*. Hot Chilli's Computer & Life. https://blog.naver.com/pakseung98/70117620461

Institute for Global Industry, Tsinghua University, WeChat Codeconomy Research Group, Tencent Research Institute (2020). *Mashang jingji yingxiangli baogao [Codeconomy influence report]*. Tencent.

Introna, L. D. (2011). The enframing of code: Agency, originality and the plagiarist. *Theory, Culture & Society*, *28*(6), 113–141. https://doi.org/10.1177/0263276411418131

Jiang, C. (2019, May. 1). QR is king. *Logic Magazine*, *7*. https://logicmag.io/china/qr-is-king/.

Kaminska, A. (2018). Storing authenticity at the surface and into the depths: Securing paper with human- and machine-readable devices. *Intermédialités/Intermediality*, *32*. https://doi.org/10.7202/1058474ar.

Kato, H., & Tan, K. T. (2005). 2D barcodes for mobile phones. 2005 2nd Asia Pacific Conference on Mobile Technology, Applications and Systems, Kolkata, India, 1–8. https://doi.org/10.1049/cp:20051578

Kato, H., & Tan, K. T. (2007). Pervasive 2D barcodes for camera phone applications. *IEEE Pervasive Computing*, *6*(4), 76–85. https://doi.org/10.1109/MPRV.2007.80

Kitchin, R., & Dodge, M. (2014). Barcodes and RFIDs. In N. Thrift, A. Tickell, S. Woolgar, & W. H. Rupp (eds.), *Globalization in practice* (pp. 268–271). Oxford University Press.

Kjellberg, H., Hagberg, J., & Cochoy, F. (2019). Thinking market infrastructure: Barcode scanning in the US grocery retail sector, 1967–2010. In M. Kornberger, G. C. Bowker, J. Elyachar, A. Mennicken, P. Miller, J. R. Nucho, & N. Pollock (eds.), *Research in the sociology of organizations* (pp. 207–232). Emerald Publishing Limited. https://doi.org/10.1108/S0733-558X20190000062013

Lauer, J. (2020). Plastic surveillance: Payment cards and the history of transactional data, 1888 to present. *Big Data & Society*, *7*(1), 1–14. https://doi.org/10.1177/2053951720907632

Liu, Y., Yang, Ju, & Liu, M. (2008) Recognition of QR code with mobile phones. 2008 Chinese Control and Decision Conference, 203–206). https://doi.org/10.1109/CCDC.2008.4597299

Mandel, R. (2002). A Marshall Plan of the mind: The political economy of a Kazakh soap opera. In F. D. Ginsburg, L. Abu-Lughod, & B. Larkin (eds.), *Media worlds: Anthropology on new terrain* (pp. 211–228). University of California Press.

McCurry, J. (2020). December 11). *I'm pleased it is being used for people's safety": QR code inventor relishes its role in tackling Covid*. The Guardian. https://www.theguardian.com/technology/2020/dec/11/qr-code-inventor-relish-its-role-in-tackling-covid

Nguyen, D. (2022). Convenient efficiency: A media genealogy of QR codes. *New Media & Society*, 1–21. https://doi.org/10.1177/14614448221141086.

Okazaki, S., Li, H., & Hirose, M. (2012). Benchmarking the use of QR code in mobile promotion: Three studies in Japan. *Journal of Advertising Research*, *52*(1), 102–117. https://doi.org/10.2501/JAR-52-1-102-117

Plantin, J.-C., & de Seta, G. (2019). WeChat as infrastructure: The techno-nationalist shaping of Chinese digital platforms. *Chinese Journal of Communication*, *12*(3), 257–273. https://doi.org/10.1080/17544750.2019.1572633

Sandvig, C. (2013). The Internet as infrastructure. In W. H. Dutton (Ed.), *The Oxford handbook of Internet studies* (pp. 86–106). Oxford University Press.

Schmidt, M., Thoroe, L., & Schumann, M. (2013). RFID and barcode in manufacturing logistics: Interface concept for concurrent operation. *Information Systems Management*, *30*(2), 100–115. https://doi.org/10.1080/10580530.2013.773801

Shimota, K. (2022). *The first superapp: Inside China's WeChat and the new digital revolution*. Earnshaw Books.

Soon, T. J. (2008). QR code. *Synthesis Journal*, *8*, 59–78.

Staab, P., & Nachtwey, O. (2016). Market and labour control in digital capitalism. *TripleC: Communication, Capitalism & Critique*, *14*(2). https://doi.org/10.31269/triplec.v14i2.755

Steinberg, M. (2020). LINE as super app: Platformization in East Asia. *Social Media + Society*, *6*(2), 1–10. https://doi.org/10.1177/2056305120933285

Steinberg, M., & Li, J. (2017). Introduction: Regional platforms. *Asiascape: Digital Asia*, *4*(3), 173–183. https://doi.org/10.1163/22142312-12340076

Stevens, H. (2019). Digital infrastructure in the Chinese register. *Made in China Journal*, *4*(2), 84–89. https://doi.org/10.22459/MIC.04.02.2019.11

Sun, A., Sun, Y., & Liu, C. (2007). The QR-code reorganization in illegible snapshots taken by mobile phones. 2007 International Conference on Computational Science and its Applications (ICCSA 2007), Kuala Lumpur, Malaysia, 532–538. https://doi.org/10.1109/ICCSA.2007.86.

Tai, Z., Yu, X., & He, B. (2021). Locked down through virtual disconnect: Navigating life by staying on/off the health QR code during COVID-19 in China. *Convergence: The International Journal of Research into New Media Technologies*, *27*(6), 1648–1662. https://doi.org/10.1177/13548565211047157

Thrift, N. (2004). Remembering the technological unconscious by foregrounding knowledges of position. *Environment and Planning D: Society and Space*, *22*(1), 175–190. https://doi.org/10.1068/d321t

WeChat, Tsinghua China Data Center, Tencent Research Institute (2020). *2020 Mashang jingji "zhanyi" baogao [2020 Codeconomy "Epidemic war" report]*. (p. 104). Tencent.

Weightman, G. (2015). *Eureka: How invention happens*. Yale University Press.

Weir, M. (2010). *QR codes & mobile marketing for the small business owner*. CreateSpace.

Woodland, N. J., & Silver, B. (1952). *Classifying apparatus and method (United States patent Office patent No. US2612994A)*.

Author biography

Gabriele de Seta is a Postdoctoral Researcher at the University of Bergen, where he is part of the ERC-funded project "Machine Vision in Everyday Life". His research work, grounded on ethnographic engagement across multiple sites, focuses on digital media practices, sociotechnical entanglements and vernacular creativity in the Chinese-speaking world.