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Application of New Technology in Education: Design and Implementation of Graduate Certificate Model Based on Intelligent Graph Element Technology

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Abstract: Modern information technology empowers education and infuses new vigor into educational innovation. However, current university diplomas are old-fashioned, not connected to information technology, and easy to copy. Two-dimensional code technology, widely popular in China because of its intuitive, simple, convenient, and other advantages, should be integrated into the field of education. Two-dimensional code technology is the advanced form of graphic code technology. However, through the analysis of the current situation of graphic code technology research and education applications including two-dimensional code, there are no actual cases of graphic code technology applied to graduation certificates, leaving a blank field of research. This is mainly due to the defects and limitations of the existing graphic code technology, so a new intelligent graph element technology (IGET) is proposed here. Intelligent graph element technology integrates the functional advantages of two-dimensional code and overcomes the issues of certificates being easy to forge and difficult to verify, by adding intuitive, discernible, and valuable new functions, suitable for the functional requirements of the graduation certificate. Based on intelligent graph element technology, a novel graduation certificate management system model is constructed here, and a graduation certificate is designed and implemented. Compared with the traditional graduation certificate, the graduation certificate based on intelligent graph elements has the advantages of being intuitive and readable, and having information security, a large amount of information, and intelligent anti-counterfeiting, verification, and traceability mechanisms. The application of intelligent graph element technology in the design and research of college graduation certificates opens a new window of digitization and informatization innovation for traditional college graduation certificates, and provides reference for other innovative applications of intelligent graph element technology in the field of education.

Keywords: intelligent graph element technology; sustainable educational application; design of university graduation certificate; security and anti-counterfeiting



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1. Introduction

At present, two-dimensional code is one of the information technologies with rapid development, wide versatility, and strong permeability in the world. For example, in China, the application of two-dimensional codes has become a new way of life for Chinese people, via mobile payments, scanning for travel, product coding, information queries, etc. Two-dimensional code has become indispensable and has been widely used in all fields of daily life because of its convenience and rapidity. Nevertheless, the practical application of two-dimensional code in education does not stand out.

However, in education, many scenarios require the application of two-dimensional code [1–3], such as the design of college graduation certificates. The importance of gradua-

tion certificate is obvious, because it largely represents the academic and ability level of the certificate holder. Job recruitment, rank evaluation, application for scientific research projects, and even postgraduate entrance examination and study abroad all require a degree, and it is difficult to obtain a higher degree. Therefore, people attach great importance to the authenticity of diploma certificates. However, fake graduation certificates have long been a headache for people, and there is no stopping them. There are three main deficiencies in present diplomas: first, the information content of diplomas is scarce. Second, diplomas are easy to forge, and verification work is troublesome. Third, it has not been fully integrated into the flood of educational information. For example, in China, if you want to verify the graduation certificate of a university, you need to check the “Xuexin” website, which not only takes time and trouble, but also has some economic costs. Moreover, some real diplomas cannot be verified due to time limits and other reasons. If QR codes are applied to graduation certificates, verification will become intuitive and convenient. By scanning the code, more information about a person’s degree can be easily found. Therefore, the application of two-dimensional code for graduation certificates is worth further study and practice. So far, however, there have been few practical cases of QR codes being applied to graduation certificates, despite two-dimensional code being widely used and education information technology constantly innovating. We believe the main reason for this is that the two-dimensional code itself does not have anti-counterfeiting properties, and certificates with two-dimensional code can be easy to copy, especially coupled with counterfeiting technology. Therefore, the security of QR codes has become a major obstacle to their application in graduation certificates.

It is necessary to study the informatization and digital innovation of graduation certificates, which is one of the difficult problems that must be solved in the all-round reform of education digitalization. China’s Education Informatization 2.0 Action Plan (2018) clearly points out that education informatization should not only realize normal applications, but also achieve all-round innovation [4], and the informatization innovation of university diplomas should belong to the research category of education informatization. AECT (Association for Educational Communications and Technology) defines Educational Technology 94 as follows: educational technology is the theory and practice of designing, developing, utilizing, managing, and evaluating related resources and processes in order to promote learning. A diploma is the evaluation of learning results, and its information innovation belongs to the research content of educational technology, and is also the duty of educational technology researchers.

Specifically, with this study, we sought to solve the following major problems:

- (1) How to realize the digitization and informatization of college diploma;
- (2) How to prevent college diplomas from being counterfeited and forged; and
- (3) How to help the verifier obtain more information and improve the efficiency of the verification.

The purpose of this study was to use advanced information technology to achieve efficient information from graduation certificates, so as to expand the application of new technology in education. In order to solve the above problems, we first innovate the two-dimensional barcode technology, and put forward a new generation of graphic code technology, namely, intelligent graph element technology (IGET), which can be anti-counterfeit, verifiable, intuitive, readable, and have information security, intelligent identification, and verification of convenient functional advantages, all of which are suitable and efficient graduation certificate functional requirements. Based on intelligent graph element technology, we designed and researched a management system model for innovative university graduation certificates.

2. Literature Review

2.1. Figure Code Technology

Figure code technology uses figure, not binary data “0” and “1”, as words of communication between persons and machines, or among machines, to store, disseminate, and

present information. We divide this code system, which transmits information by geometric patterns, into two kinds: barcode technology and graphic code technology.

2.1.1. Barcode Technology

Barcode technology is the combination of photoelectric technology, communication technology, computer technology, and printing technology, and is an important graphic recognition technology. In terms of form, barcodes can be divided into one-dimensional barcodes and two-dimensional barcodes.

(1) One-dimensional code.

One-dimensional barcode is the earliest barcode, which is the graphic identifier used to represent a group of information by using multiple black bars and white spaces with different widths arranged in accordance with certain coding rules. Barcodes were invented in the 1940s by two students in Germany who created the bull's eye circular barcode. Joe Wood Land and Berny Silver in the U.S. started working on coding food items and corresponding automatic identification devices. In 1949, the first machine-readable barcode was registered: "Bovine eye Code" [5,6]. Since then, countries around the world have carried out in-depth research on barcodes. In 1973, the United States Unified Coding Association (UCC) established the UPC barcode system, and realized the standardization of the code system. By the end of 1990, there were more than 40 kinds of barcode systems in the world, and the corresponding automatic identification equipment and printing technology have also made great progress. Since the mid-1980s, some Chinese universities, scientific research departments, and export enterprises have gradually deepened the research, promotion, and application of barcode technology.

Originated in the 1940s, studied in the 1960s, applied in the 1970s, and popularized in the 1980s, barcode and barcode technology, as well as various application systems, have caused great changes in world circulation. Barcode as a computer language that can be printed is called "computer culture". In the 1990s, the international circulation field regarded barcode as the "ID card" for commodities to enter the international computer market [7]. Now, various countries and regions in the world are generally using barcode technology. Its application field is expanding, and has gradually penetrated into all areas of people's living and production: industrial production, circulation of commodities, logistics, books, information and item management, product logos, and education, such as teaching materials, books, learning video discs, etc.

Barcode technology has the characteristics of fast input speed, high reliability, easy use, and low production cost. However, there are also many shortcomings: first of all, because barcode is open-source, there is no sovereign control; second, barcodes can only be horizontally coded, have limited length and small capacity, and display less information; and last, they can label goods, but do not easily describe goods.

(2) Two-dimensional code.

In order to solve the problem of small information storage capacity of one-dimensional barcodes, researchers began to investigate barcodes that can represent more information, namely, two-dimensional barcodes. The two-dimensional barcode, or QR code, was invented in 1994 by Hirohara Teng of Japan [8]. Two-dimensional code has two forms of layer arrangement and matrix, and the common two-dimensional code is Quick Response (QR). It uses geometric graphic principles and black-and-white graphics instead of binary "0" and "1" to record data symbol information [9]. QR codes popular in China are mostly matrix, with black squares representing 1 and white squares representing 0.

The emergence of QR code is a milestone in the development of barcode technology. After its emergence, two-dimensional code was not applied in practice at first; only in the past 20 years has it been widely used [10]. In 2001, some places in China launched the anti-counterfeiting technology of 2D barcode plus spurting code [11]. In 2011, Wei Xu, founder of China Skynet, applied for the registration of "two-dimensional code scan patent" [12]. Coupled with the birth of WeChat in China in 2011, the QR code exploded in popularity in China [13].

Compared with one-dimensional barcode, two-dimensional code has the following characteristics: first of all, the information capacity is large, nearly 100 times higher than the one-dimensional barcode information capacity. The figure can contain 2710 numbers or 1108 bytes or more than 500 Chinese characters. Second, the code range is wide and the form is diverse. It transcends alphanumeric limits and can encode pictures, sound, text, signatures, fingerprints, and other information that can be digitized; However, most two-dimensional code technology has not reached the practical application of the above, but set videos, websites, and other links as coding, or pictures and text as background settings. Third, it has high reliability of decoding. The decoding error rate of ordinary barcodes is about 2%, while the error rate of 2D barcodes is no more than one in ten million. Fourth, it has a strong ability to correct errors and resist damage. If the damage area does not exceed 50%, the information lost due to contamination and damage can be translated as usual. Fifth, it is easy to make and of low cost. We can print 2D barcode on paper, cards, PVC, or even metal surfaces. This increases the cost of ink only. Last, it is easy and fast. As long as a camera can support scanning QR codes, the software can automatically direct to a website or access to information resources [14].

However, QR codes still have many shortcomings.

Firstly, there exist potential security issues. Encoding and decoding rules of two-dimensional code are open, and the overall security is low. Two-dimensional code itself does not have anti-counterfeiting functions, making it easy to copy or forge. If the QR code is counterfeited as a security label, then the QR code will lose its anti-counterfeiting function. If the QR code that holds one's personal information is copied, then that personal information could be used by criminals. As an important carrier of mobile Internet and information transmission, QR code has gradually become a new channel for virus Trojan horses and phishing websites to spread. The market commonly uses Japanese QR code, DM code in the United States, and other open-source, universal code systems that directly encode information plaintext; however, they face an increased risk of user information disclosure. For example, in two-dimensional code on train tickets, there have been cases of risk of leakage of passengers' personal information. Payment risks also exist. WeChat payment is the most common application of QR codes, and criminals often use scanning codes to pay bills, handing out red envelopes and other means to carry out fraud. For example, criminals create fake QR codes to pose as merchants' payment codes or give red envelopes. When people scan the codes, the money goes to the fraudster's account. In addition, some criminals often send small programs to clean up the zombie powder in WeChat, for fraud or other illegal activities.

Secondly, traceability is poor. At present, the two-dimensional code itself cannot be traced in the technology, so if we use it to trace a product, there is no source. Barcodes and QR codes generated in society every day cannot be directly counted.

Thirdly, it is of a linear information point arrangement, of linear storage, and relatively simple style. Although the background colors and background patterns of existing two-dimensional code are rich, the color of the two-dimensional code itself is only black and white, and thus lack naked-eye identification code attribution.

In addition, due to the linear storage of two-dimensional code, the amount of information is relatively insufficient, and the reading transaction is generally conducted online.

2.1.2. Figure Code Technology

In order to solve the problems of two-dimensional code security, linear coding, single form, less information content, and other concerns, researchers, through different methods and approaches, developed the study of graphic code technology. In 2010, Chen Shengxu from China proposed a "three-dimensional code" on the basis of two-dimensional code to enhance security and add visual attributes [15]. When the concept and function of this three-dimensional code were proposed, it was controversial. Chen Changsheng of WeChat, aiming at the security of two-dimensional code, carried out anti-counterfeiting, anti-replication research [16].

2.2. The Educational Application of Graph Coding Technology

The worldwide popularization and application of one-dimensional code and the popularity of two-dimensional code in China illuminates the innovation potential of the application of graphic code technology in the education industry [17].

In recent years, with the rapid development of information technology, educational informatization has been promoted all over the world [18]. As a new trend of information technology, the application of graph coding technology in education mainly focuses on two-dimensional code textbooks and courses [19], school books and asset management, student learning records, knowledge payment, and other aspects.

2.2.1. Two-Dimensional Code Textbooks and Courses

Teaching material is an important channel for knowledge acquisition and dissemination. It is an inevitable trend in the future to digitize paper teaching materials and make planar teaching materials three-dimensional [20]. Two-dimensional code is printed on paper textbooks. Learners scan the code and then link to the website platform or download the app to obtain rich digital resources [21]. Such textbooks are called two-dimensional code textbooks and have become new forms of textbooks. This not only enriches the form of textbook resources and realizes the extension of learning content, but also creates a more convenient self-learning environment for learners. In addition, some researchers have proposed combining QR code with smart phones to be used in classroom teaching [22,23].

In 2006, CAI Jingsheng first proposed the application of two-dimensional code technology in publications, believing that two-dimensional code technology can “meet the information requirements of all production links of the press and publication industry” to a greater extent [24]. In 2007, Zhonghua Book Company, Guangxi Normal University Press and Chunfeng Literature Publishing House in China tested the two-dimensional code mobile website service, providing press information, new book information, chapter trial reading, and other functions [25]. In 2011, Chinese Tencent launched WeChat. The explosive growth of WeChat users provides conditions for the development and application of two-dimensional code in books and textbooks. The year 2012 is known as the year of the outbreak of QR codes in Chinese books [26]. Since then, the research and application of two-dimensional code in books and textbooks have attracted wide attention. In July 2013, East China Normal University Press released the Master Of Problem Solving (Micro Video Version), which sets a two-dimensional code beside each sample problem and enables users to watch the corresponding video explanation for free by scanning the code, becoming one of the leading forces to create a new model of “mobile learning” [27]. In 2014, China Higher Education Press launched its QR code service platform.

Since 2006, the use of two-dimensional code was limited to the book cover or back cover, and used more for the publishing house’s promotional means [28], as the focus on book management gradually expanded to book marketing. Later, the application of two-dimensional code in books showed a trend of deep integration with the book content. By scanning the code, readers can directly obtain various forms of learning resources [29]. Two-dimensional code book content gradually shifted from focusing on educational books to medical books, science and technology books, children’s books, and others.

2.2.2. University Books and Assets Management

(1) University asset management.

Two-dimensional code recognition technology can be used to complete the rapid collection, statistics, and traceability of school asset information. The relevant information such as purchase time, unit price, quantity, storage location, and person responsible for each piece of teaching equipment and other assets will be generated and pasted on the asset equipment to facilitate management. Scanning the two-dimensional code can not only track the relevant information of the equipment, but also show the assets, teaching equipment usage, precautions, and other relevant information, and is easy to use. Therefore, two-dimensional code can make asset equipment management convenient and intelligent [30].

(2) University library management.

The barcode on the International Standard Book Number (ISBN) has been used to manage books for more than half a century since 1967. This barcode management method requires manual maintenance of a CIP (Cataloguing In Publication) database. The contents of CIP need to be obtained from the publishing house or entered manually, which is time-consuming and makes it difficult to ensure the integrity of the data for a large number of books management. This is why we have adopted QR codes instead of barcodes to manage books [31]. QR codes can contain more complex data that can be read directly, such as text, images, and web links. It can include the contents of the CIP database directly in the two-dimensional code, and realize the automatic entry, scanning, processing, and identification of borrowers [32]. In China, two-dimensional code has now entered the practical application of book management. The application of two-dimensional code in book management is the need of modern book management, which reflects the improvement of Chinese book management level.

2.2.3. Learning Record

Two-dimensional code technology can be used to record students' learning process, academic performance, and other evaluation results for a long time, and facilitate access, tracking, and verification [33]. The content of each dimension in students' learning is presented in the form of two-dimensional code. It can not only collect learning process data, but also generate students' electronic files and form a Big Data analysis model [34,35]. It is convenient for schools, teachers, parents, and students themselves to fully understand each student's unique learning trajectory. It can help students to devise a career plan suitable for them. It is conducive to the all-round development of students and can also reduce the burden of teachers' work and reduce the pressure of management [36]. In addition, it can be used as an effective proof for students to apply for a job after graduation, which is convenient for employers and institutions to understand and verify the applicant's real situation.

2.2.4. Knowledge Payment

At present, it is not new for learners to pay through QR code after receiving teaching services in China. With the rise of knowledge payment platforms such as Fenaan, Zhihu Live, and Himalayan FM, it has gradually become commonplace to pay for valuable knowledge, experience, and insights [37,38]. WeChat and Alipay are adopted in many cases of learning consumption, and cash payment is becoming less common. Considering the security problem that the two-dimensional code can be copied and the recognition rate of the number is higher than the character, the payment code is generally composed of a string of 18 digits. After the learners scan the QR code, payment can be completed in a few steps according to the requirements of the online learning resource provider, which is simple and convenient.

In addition, QR codes are also used for student identification, intellectual property protection, and traceability [39].

2.3. The Information Design of Graduation Certificate

There are few studies on the informatization innovation of graduation certificates. In 2011, the author F.L. used a proxy signature system to create an electronic graduation/degree certificate management system model, and implemented the design scheme of electronic graduation certificates. This scheme does not need the support of the CA (Certificate Authority), and can realize the transfer of signature right. Moreover, it can effectively prevent diploma/degree fraud and improve verification efficiency [40].

To sum up, the current research results of two-dimensional code in education applications are mostly focused on theoretical research, and there is lack of technical research [41]. At present, there is no research literature or practical application case in which two-dimensional code is applied to the design of a higher graduation certificate. This

is likely because two-dimensional code is only a single style and does not offer enough security. If the QR code on the diploma as a security label can be counterfeited, the diploma will lose its security function. If the QR code used for the diploma itself cannot be traced, then the diploma will not be able to achieve intelligent verification. If the QR code carrying personal information is copied, the personal information will be exposed, and even used by criminals. In short, two-dimensional code cannot be anti-counterfeiting, cannot be traced, and cannot achieve effective verification, so it can not be applied to the design of college graduation certificates.

Based on this, in order to solve the above problems, we put forward a graduation certificate system model and design scheme based on intelligent graph element technology.

3. Graduation Certificate System Model Based on IGET

Modern information technology has brought fresh air to the reform of education and teaching [42]. However, current diplomas are old-fashioned, are not geared to information technology, and are easy to copy and fake. A good diploma should have the following characteristics: authoritative, true, anti-counterfeiting, reliable, verifiable, generous, intuitive, beautiful, etc. Among them, the certificate's anti-counterfeiting (authenticity), verifiability, intuitiveness, and readability are particularly important. In view of the serious phenomenon of graduation certificate forgery at present, and the fatal defects such as troublesome verification work and small amount of information that can be displayed, it is necessary to improve graduation certificates. Intelligent graph element technology (IGET) can be well adapted to the above functions and characteristics, and is one of the effective methods to realize the informatization of graduation certificates.

3.1. Intelligent Graph Element Technology

In view of the small information capacity of one-dimensional barcode and the poor security of two-dimensional barcodes, we carried out research and exploration of a new generation of graph code technology to overcome their shortcomings. The design idea of the new generation of graphic code technology is to retain the advantages of two-dimensional code functions, adding multiple dimensions and variables, naked-eye recognition, accurate interpretation, high encryption, and anti-counterfeiting and anti-copy functions. It controls the storage, transmission, and interpretation of information through geometric algorithms and structured encryption with three-dimensional interwoven curve geometry (graph) [43]. Since 2015, we have conducted in-depth research on the intelligence, security, and practicability of graph code technology.

Different from other researchers' methods and paths, we carried out research on the new generation of graphics code technology, and proposed the concept of intelligent graph element technology in 2020. Graph element refers to basic graphic elements, such as the basic plane geometry, square, rectangular, trapezoidal, circular, diamond, oval, etc.; or basic three-dimensional geometry, such as square, rectangle, cylindrical, and square column; and color (red, orange, yellow, green, green, blue, purple, grey, pink, black, white, brown) combination. Intelligent graphic element technology uses graphics instead of the current computer numbers "0, 1", for communication between human and machine, and from machine to machine. The storage, dissemination, and display of information are in an intuitive form. Different from open-source barcodes or two-dimensional codes, which store information in a linear matrix formed by interlacing straight lines horizontally and vertically, graph element (see Figure 1) technology uses curve interlacing or straight lines interlacing with curves; that is, using graph element encoding to store information. Its drawing rules are diverse and drawing styles are rich. It can attach other specific information and use geometric algorithms and structured encryption. Therefore, with the integration of other intelligent algorithms and technology, we call it intelligent graph element technology. The resulting graph code is called intelligent graph element code, or intelligent three-dimensional code, referred to as intelligent code, smart code, identity code, and personality code, as shown in Figure 1.



Figure 1. Intelligent graph element code.

The key algorithms and technologies of intelligent graph element technology are closed-source, and the core components are composed of the coder and decoder. In the process of code forming, additional information encryption, geometric algorithm for pattern encryption, pattern diversity encryption, and other methods are used to implement information implantation into the map, to build an additional password. According to the different mapping rules and algorithms, the encryption process is not completely the same. The decoder can interpret the original information on the pattern according to the rules of drawing, encryption information, and algorithm.

3.1.1. Principles

Different from 0.1 digital coding, as well as linear coding of barcode and two-dimensional code, intelligent graph element technology adopts geometric coding and controls the storage, dissemination, and interpretation of information with geometry and color. Its essence is that the information is replaced by the traditional digital code, and all the information data are stored in the geometric structure. Encoding and decoding are two critical processes. The coding is accomplished by the coder, which is composed of a code disk generator and a code element generator. Decoding is completed by the decoder. Decoding must have the decoding key, one code one key, and take root a analysis management form.

3.1.2. Features

Compared with barcode and traditional 2D barcode, intelligent graph element code has more advantages, and its characteristics are as follows.

Firstly, the style is rich. It can not only generate black and white code and color code, plane code and stereo code, but also generate static code and dynamic code. Based on appearance, the traditional two-dimensional code has a significant difference.

Secondly, the security problem of graphic code technology is solved fundamentally. It has various encryption rules, keys, and high security. It cannot be copied or forged, and has a good tracing function. The information in the image code cannot be changed or counterfeited by the outside world or others. Only the code owner or agent can use the key to open and change the information in the code, and the code key has direct control and traceability for each code.

Thirdly, the reading speed is fast, and it has large amount of information. Without scanning the code, you can directly identify the identity of the code visually, and know whose code it is. It solves the problem of code identity completely, and the code has a destination. The host is the master of the code, and the host is the source of the code's identity. The amount of information stored is about 3–5 times larger than the ordinary two-dimensional code.

Fourth, it has intelligence due to the integration of artificial intelligence and Big Data technology. The “intelligence” of intelligent graph element is mainly manifested in intelligent anti-counterfeiting, intelligent verification, intelligent tracking, and intelligent recommendation, and can provide precise positioning and personalized services [44].

Lastly, it can realize personalized customization service. According to users' requirements, not only the style can be customized, but also the code owner has the right to set

the scanner and obtain the code reading information and the time and duration of reading information, and the whole network remote control can be realized for a long time.

In addition, for intelligent graph element technology, the code scanning is not restricted by the network, and can be read both online and offline.

3.1.3. Educational Applications

Intelligent graph element technology can be widely used in the field of education because of its advantages such as fast, intuitive readability, information security and non-replication, independent personality and customization. For instance, can be used for student management systems, educational systems, learning support systems, knowledge copyright systems, diploma certificate management systems, etc. However, at present, such application are rare.

3.2. Research Ideas

Based on intelligent graph element technology, we designed a graduation certificate system model with intuitive, naked-eye readability, simple and reliable identification, and anti-counterfeiting measures, and that is difficult to copy. The new intelligent graphic code graduation certificate we designed (Figure 2) is significantly different from the traditional graduation certificate (Figure 3). On the basis of the traditional graduation certificate, the information element of “graph code” is added. This graph code is not a traditional two-dimensional code, but a new type of intelligent graph code. Moreover, the text information on the graduation certificate and the information source in the graph code are completely consistent. Figures 2 and 3 are the intelligent graph element graduation certificate and the traditional graduation certificate, respectively.

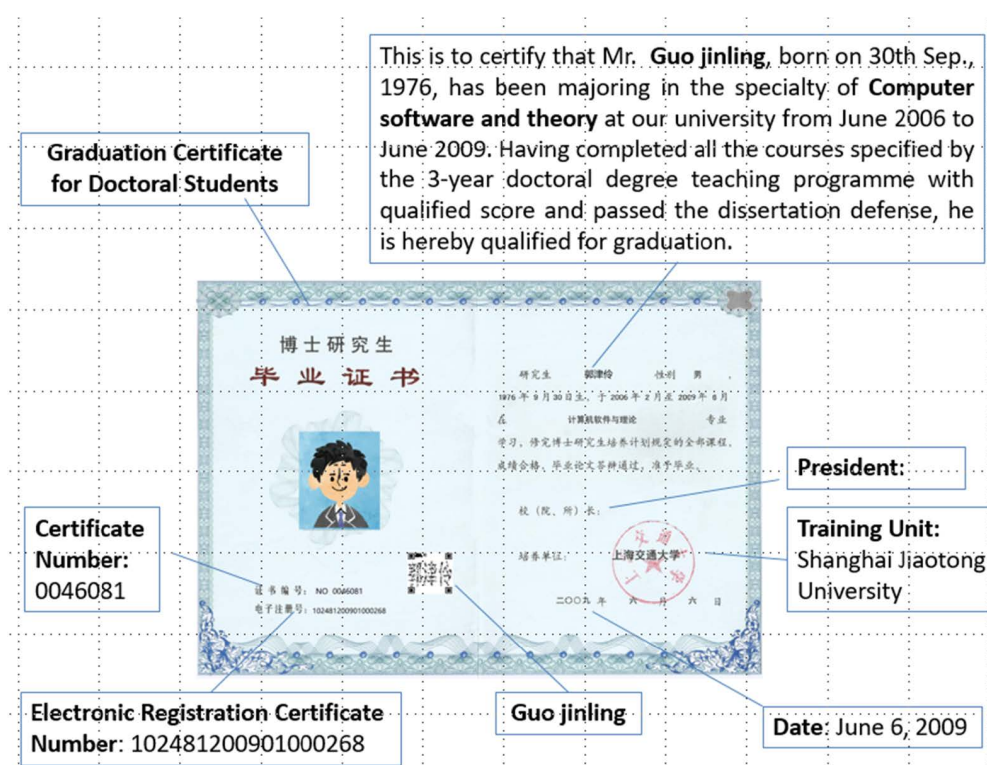


Figure 2. New smart graph code graduation certificate.

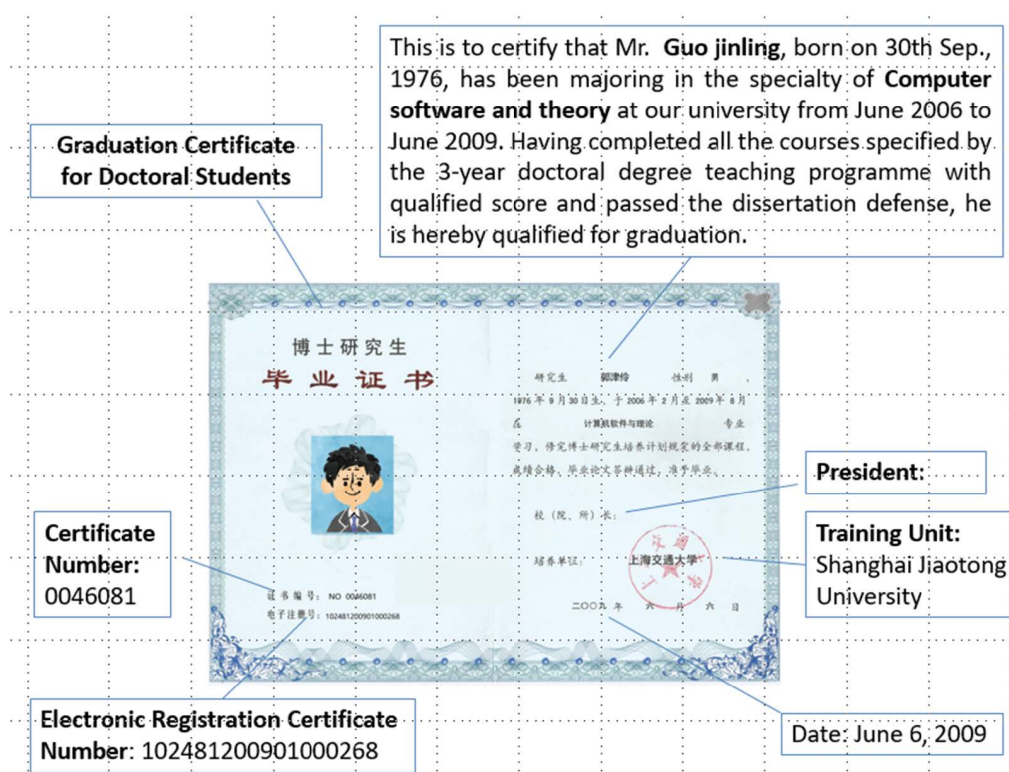


Figure 3. Traditional graduation certificate.

The intelligent graph element graduation certificate management system is designed as follows. Firstly, students' graduation school information, personal basic information, and learning data are collected. Part of the data can be filled in or modified or deleted by students. Then, the national administrative department of education, the academic affairs office of the school, and the individual students sign the graduation data collected to perform the authentication. Then, the signed data will be transmitted to the graph code generation system and the graduation certificate generation system to complete the graduation certificate design and the graph code generation. At the same time, throughout the whole process of data collection, authentication, graph code generation, and graduation certificate production, the data are processed with anti-counterfeiting encryption. Finally, the graduation certificate is scanned and authenticated. If the scanned information is identical with the information on the diploma and can be traced back to the signatures of the national educational administration and the educational administration department of the student's school, then the diploma is true and reliable. Otherwise, it is a fake certificate.

3.3. Mode of the Graduation Certificate Management System Based on IGET

The graduation certificate system based on IGET we designed (as shown in Figure 4) consists of the following subsystems: data acquisition system, personalized design system, authentication system, encryption system, certificate realization system, and verification system.

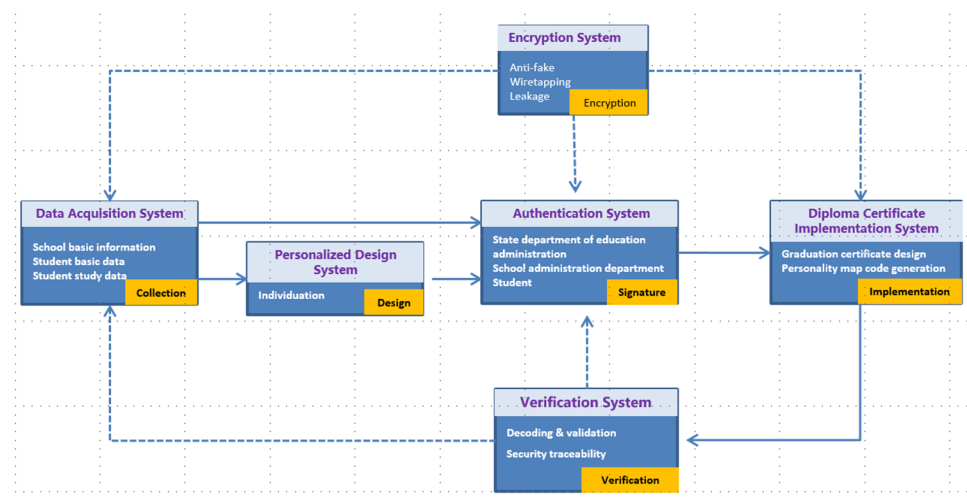


Figure 4. Mode of the intelligent graph element graduation certificate management system.

(1) Data acquisition system. This system mainly completes the basic information on the graduation certificate and the data information needed to generate the graph code, mainly including school information, such as school name, school badge, and address; basic personal information of students, such as name, sex, age, date of birth, ID number, and native place; and learning data, such as academic performance and assessment, highlights of students in school, rewards, and punishments.

(2) Personalized design system. According to the professional needs and students' personality characteristics, a graphic code style design will be carried out. For example, if the graphic code displays students' names, students can design their favorite artistic characters within the prescribed scope to highlight their professional characteristics and expertise, which is conducive to career development.

(3) Authentication system. The system mainly completes the collection of student information by the national education administrative departments at all levels and the school educational administration departments strictly examine, confirm, and sign, and at the same time, individual students should also sign for approval. The issuance of graduation certificates in any country is extremely serious and prudent. For students who have completed their studies, it is necessary to ensure that "one person one certificate" is issued.

(4) Certificate realization system. It mainly completes the generation of drawing codes, the design of graduation certificates, and the printing of certificates. The diploma realized by this system can be directly identified by the naked eye due to the incorporation of new graphic code technology, and it is not easy to fabricate.

(5) Encryption system. Encryption runs through the whole process of student data collection, personalized design, graduation information signature authentication, and diploma certificate implementation. As the graph coding mechanism is not open, one code, one key ensures the security of the information processing and the information within the code.

(6) Anti-counterfeit verification system. This "verification" has two meanings: one is to verify the authenticity of paper diploma certificates. The second is to verify the authenticity of the information by decoding the graphic codes of diploma certificates, and to trace the administrative review of graduation certificates, signature institutions, and the circulation process of student information. Compared with the complexity of traditional diploma certificate verification, this verification process is simple, clear, and secure. In addition, the system also embodies the intelligent recognition, intelligent tracking, and intelligent anti-counterfeiting functions of intelligent graph element technology.

4. Realization of Graduation Certificate Case Based on IGET

The new graduation certificate we designed based on IGET has added a “graphic code” to the traditional appearance of graduation certificates. This graph code is the key difference between the new graph code graduation certificate and the traditional graduation certificate. For the graph code on the graduation certificate of intelligent graph, the mechanism and process of its code formation, decoding, and verification are unique. The following takes the graduation certificate based on IGET of Shanghai Jiao Tong University (as shown in Figure 5) as an illustrative example.

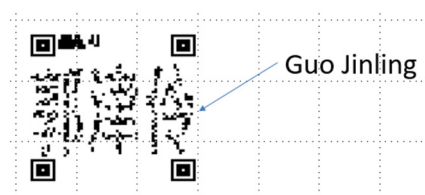


Figure 5. The smart map code on the diploma.

4.1. Graduation Certificate Encoding

The graph code generation for a graduation certificate is completed by the coder. The graph code management center server generates a graph code printed on the graduation certificate for each graduate according to the time stamp, the student’s graduation information, and the national Ministry of Education and university authorization. For example, the figure code on the graduation certificate of “郭津伶 (Guo Jinling)” (fictitious name), a student of Shanghai Jiao Tong University, is composed of his name, as shown in Figure 5. The information in the code is composed of the student’s basic information (such as name, gender, photo, native place, ID number, and length of schooling); learning data; personalized design; signature authentication by the Ministry of Education, Shanghai Jiao Tong University, and Guo Jinling himself; and additional information (such as certificate number and issuing date). The graph codes are generated by geometric algorithms, structured encryption, and diagramming rules. Guo Jinling can customize the parameters, directly participate in the design of the graduation certificate diagram code, and create his own image code. For example, he can choose the font form and color of his name in the diagram code. Due to the additional information, geometric algorithm, pattern diversity, and other encryption schemes, the application security of the diploma can be guaranteed. With the increase in information amount and code elements, the structure and shape of the picture code on the graduation certificate will be more abundant, especially the color code attached, which is easy to print or display in electronic products, and convenient to scan, transmit, and interpret information.

4.2. Graduation Certificate Decoding

The pattern, text, and other picture codes on the graduation certificate have the dual information attributes of human naked-eye interpretation and machine interpretation, so that the graphic information seen by the human naked eye and the pattern information interpreted by machine can be unified on the same carrier, and can be directly interpreted online and offline. For example, when we see the image code of his name on his diploma, we can know that it is his diploma even if the text beside the diploma is damaged. Machine interpretation is completed by the decoder. After the body image code is entered into the image input device, the decoder can interpret the original image, shot image, screenshot image, printed image, etc., and interpret the original or additional information on the pattern according to the drawing rules and encryption algorithm, both online and offline. For example, the following information can be seen in the decoding of Guo Jinling’s diploma: Guo Jinling; male; native place is Jiangsu, China; born on September 30, 1976; from 2006 to 2009, he majored in computer software theory at Shanghai Jiao Tong University and graduated on 6 June 2009. It also shows that the certificate is approved by the Ministry

of Education and Shanghai Jiao Tong University, is issued by the president, and has the certificate number and other basic information. Not only is it consistent with the text on the right side of the code above the diploma, but more information can be read. For example, the student won an invention prize in his sophomore year and a first-class scholarship in his junior year.

4.3. Graduation Certificate Verification

The school has customized a map code for each graduate to print on the diploma, “one code for each person”. This map code records each student’s graduation information, and can be verified quickly and effectively. Take the graduation certificate of Shanghai Jiao Tong University as an example again. The graduation certificate we designed has four layers of insurance and verification methods as follows: (1) Eye comparison. The picture code on the graduation certificate is composed of a student named “Guo Jinling”. At present, our picture code technology is original and no other picture codes of the same form have been found. By the “Guo Jinling” shown in the figure code, the naked-eye information can be preliminarily identified. (2) Photo comparisons. After scanning the code, if the photo in the code is consistent with the photo on the diploma and the holder “Guo Jinling” himself, it is the real certificate. Otherwise, the certificate is false or requires further validation. (3) Information comparison. The key can be used to verify the anti-counterfeiting of the image code. The verification authority that can be traced back to the graduation certificate is the Ministry of Education and Shanghai Jiao Tong University, and the issuing authority is Shanghai Jiao Tong University. One can also query the learning process of “Guo Jinling” by comparing the text information on the graduation certificate, and thus determine the authenticity of the certificate. If the diploma is true, then the information in the diagram code is the same as the text information of the diploma. Otherwise, the certificate is false or requires further validation. (4) Identify the display. If it is a real certificate, the reading software or equipment can identify the code diagram, and if it is a fake certificate, it is unreadable. The verifier will see a prompt “The student information does not exist, please contact the issuing authority” or “This certificate is suspect”. At the same time of the above verification, the GRAPH code management center server can clearly know who is using the decoder to verify the graduation certificate. If it is a fake certificate, the graph code management center server will also be alerted. The graph code management service center can show who is scanning the code for verification, and will be limited to read times, which fully reflects the intelligent characteristics of the graph code. Its verification process is shown in Figure 6.

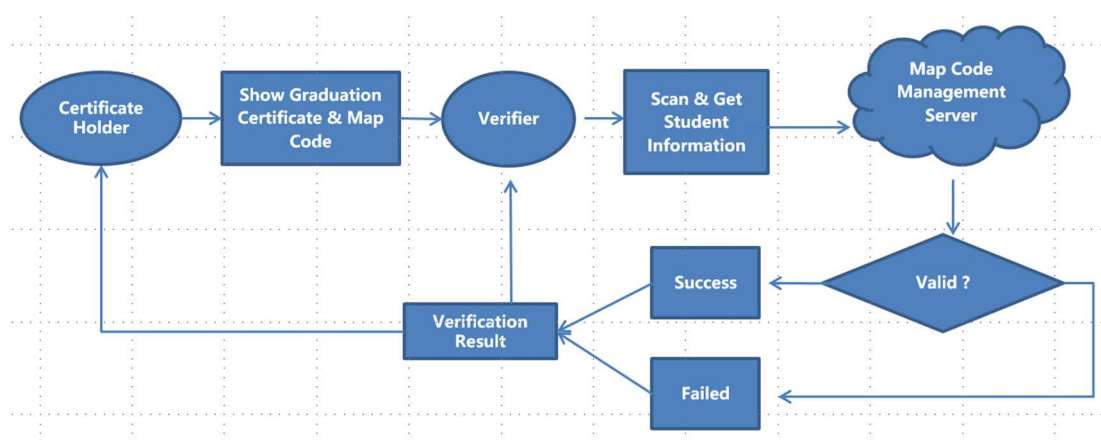


Figure 6. Graduation certificate figure code verification process.

At present, the new intelligent graph code generation rules and decoding rules are not open-source. Code information is encrypted, and each code has a matching code and

decoding key. It is difficult for others to copy and forge. Therefore, each student has a unique diploma based on intelligent graphic element technology.

4.4. Performance Analysis of Graduation Certificate Based on IGET

The core technology of this model is intelligent pixel technology, which has been studied for many years and is a continuous process. The related research has been published in journals [35,45], and the application of the graduation certificate based on the technology is being tested in several primary and secondary schools, such as Dongtai Special Education School in Jiangsu Province, Qianqiu Primary School in Sheyang County in Jiangsu Province, and Kanbei Primary School in Dongkan Town in Jiangsu Province.

(1) Comparison with the performances of the traditional graduation certificate.

According to the opinions of experts in the education system, the six performance indicators were carefully selected for the qualitative comparison between the intelligent graphics graduation certificate and the traditional graduation certificate. The six indicators are anti-counterfeiting, amount of information, verification efficiency, traceability, data privacy, and personalized design. The results are shown in Table 1.

Table 1. Performance comparison of diploma based on IGET and traditional diploma.

Performance Indicators	Traditional Diploma	Diploma Based on IGET
Anti-counterfeiting	Weak	Strong
Amount of information	Less	More, $2^n * N^n$
Verification efficiency	Low	High
Traceability	Low	High
Data privacy	Low	High
Personalized design	Low	High

The results show that compared with the traditional diploma, the diploma with intelligent graphics has the characteristics of strong anti-counterfeiting abilities, more information, and high degrees of convenient verification, traceability, data security, and personalized design. It can satisfy the requirements of the education system and students. Further analysis of the performance of the diploma is as follows.

- **Anti-counterfeiting:** The information in the smart image code on the certificate based on IGET is generated through structural encryption and special code formation rules, which cannot be tampered with or edited to ensure the exclusive rights of the diploma holder. At the same time, the smart code in the graduation certificate, using closed-source technology, cannot be copied by others. Even if it could be copied and forged, it could not be read. If the reader scans a fake certificate, the graph code management center will receive an alarm, so it is easy to crack down on counterfeiters. Therefore, the graduation certificate based on IGET can be anti-counterfeit and non-replicable, while the traditional certificate cannot.
- **Amount of information:** The amount of information on traditional graduation certificates is limited to the number of words on the certificates. However, the amount of information on the certificate based on IGET is large. In addition to the text on the certificate, a lot of information is stored in the intelligent code, which uses the basic elements of geometric graphics, shape relations, and colors as means of information expression, and there are N combinations, and the maximum storage of information can reach $2^n * N^n$. For the "0 and 1" encoding system, the maximum number of information stored is only 2^n . Graduation certificates based on IGET have more information than traditional graduation certificates, and the information is easy to read.
- **Verification efficiency:** Traditional diplomas are difficult to identify. However, for a graduation certificate based on IGET, the naked eye can directly identify its authenticity.

At the same time, scanning the code can also complete intelligent identification and verification, which is double anti-counterfeiting, simple, and convenient.

- **Traceability:** For traditional graduation certificates, tracing the origin of traditional diplomas is cumbersome. In China, the “Wang Xin” system can check authenticity of some graduation certificates using, but not all. For those who cannot use the “Wang Xin” system for verification, it will be troublesome and tedious to continue verification. For the graduation certificate based on IGET, certificate ownership is unique and has a root server, so it can be traced, and is simple and convenient.
- **Data security:** Traditional graduation certificates have no data confidentiality function. For the graduation certificate based on IGET, the storage, transmission, and presentation of students’ detailed information are integrated with encryption technology, so it is confidential and anti-counterfeiting. At the same time, through the establishment of verification correlation, each person has a unique code and a key with high information security, conducive to the protection of graduates’ personal information.
- **Personalized design:** Traditional graduation certificates cannot meet the personalized needs of students, but certificates with intelligent graphics can realize personalized and artistic designs for students and majors with special needs. The smart code style on the certificate based on IGET is also rich, which can generate text code, logo code, and art pattern code.

(2) Comparison with previously technology adopted.

There are few studies on the informatization innovation of graduation certificates. The emphases of research are different because of the different core technologies used. In 2011, we proposed a model of an electronic graduation certificate management system, which adopts proxy signature technology and does not need the support of the Certificate Authority (CA), can effectively prevent diploma fraud, and can verify the source and the integrity of information [41]. The new graduation certificate proposed in this paper adopts intelligent graph element technology, which has the characteristics of intelligence, is convenient and intuitive, has a large amount of information, ensures data confidentiality, and offers personalization, in addition to the function of preventing counterfeiting and realizing verification, according to the above performance analysis.

In conclusion, compared with the proxy signature technology previously adopted, intelligent graph element technology has many advantages in personalization and sustainable development.

5. Conclusions

In recent years, graphic code technology represented by two-dimensional code has been rapidly developed in China and other countries and regions, and has been gradually applied in the field of education [46,47]. Despite this, its application in college diplomas is rare, almost nonexistent. Due to its intuitive, concise, convenient, and other advantageous features, graph code should have a significant role in the design of college graduation certificates; however, two-dimensional code has not been used in such applications. The main reason is that the two-dimensional code itself cannot be anti-counterfeiting and cannot solve the problems of graduation certificates being easy to forge and difficult to verify. Therefore, we developed an innovative form of graph code technology, the intelligent graph element technology, which not only integrates the advantages of two-dimensional code functions, but also provides intelligence, anti-counterfeiting measures, and security. Based on intelligent graph element technology, we built a graph code graduation certificate management system model, and developed a graph code graduation certificate. Compared with the traditional graduation certificate, the graduation certificate based on IGET has the advantages of intelligent anti-counterfeiting measures, information security, a large amount of information, intuitive identification, and convenient verification.

The innovation of this research is straightforward. We explored information technology services education from a new perspective, as this is a neglected area of research. So

far, no other graduation certificate design systems and practical cases similar to the one we designed using IGET have been described.

First, we put forward the concept of intelligent graph element technology, an advanced scientific and technological innovation.

Secondly, we applied intelligent pixel technology to the graduation certificate design system, an educational application innovation. The intelligent graph element technology realizes the informatization, digitization, and intelligent transformation of college diplomas. At the same time, the security, verifiability, and traceability of the certificate are also ensured. Our study expands the breadth and depth of this research field and plays a positive role in promoting the all-round digital transformation of education.

To summarize, the application of intelligent graph element technology with China's independent intellectual property rights in the design and research of college graduation certificates offers a new opportunity for the informatization innovation of traditional college graduation certificates, and has important practical value and significance for the application and innovation of intelligent graph code in the field of education. However, accomplishing the universal circulation of college graduation certificates based on IGET can encounter certain difficulty. It is imperative to establish a unified national or international standard as soon as possible and a graphic code recognition system including two-dimensional code, which needs further in-depth study. We look forward to the advancement of intelligent graph element technology and its potential contributions to human educational and economic sustainable development.

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