Comput Syst Sci & Eng (2020) 4: 247–256

International Journal of
Computer Systems
Science & Engineering

Pattern Recognition of Construction Bidding System Based on Image Processing

Xianzhe Zhang[1,3]*, **Sheng Zhou**[2]†, **Jun Fang**[1]‡ **and Yanling Ni**[3]§

[1] *School of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan, 430070, Hubei, China*
[2] *School of Management, Wuhan Donghu University, Wuhan 430212, Hubei, China*
[3] *School of Business Administration, Hubei University of Economics, Wuhan, 430205, Hubei, China*

Bidding for construction projects is a very important and representative field in the industry. The system of bidding for construction projects has made considerable progress over the years due to the accumulation of experience and many contributions to the field. Nowadays, with the rapid development of information technology and the intellectualization of the bidding system for construction projects, the accumulation and processing of data has become an essential element of its development. In order to manage the bidding system of construction engineering reasonably, this paper proposes a system based on image processing and pattern recognition technology, which can recognize patterns in the bidding process of construction engineering. Firstly, through binarization and other methods, the bidding project documents of construction projects are preprocessed in order to extract the main information from the documents; secondly, information is obtained through pattern recognition and processing; finally, the results of pattern recognition are imported into the bidding system, and the bidding information is quickly added to the database. This paper proposes a bidding system for construction projects based on image processing and pattern recognition. The system provides a quick and convenient means of importing the bidding information and allows personnel to efficiently process the bidding documents, particularly when there are numerous documents and and too much information. Finally, the user survey shows that the proposed bidding system based on image processing and pattern recognition can reduce the workload of construction project personnel, greatly facilitating the progress of the project.

Keywords: architectural engineering; image processing; pattern recognition; bidding system

1. INTRODUCTION

The bidding system has been a part of the construction industry for many decades. As an advanced and standardized trading operation mode, the bidding system has brought remarkable economic and social benefits to construction projects. However, despite the continuous development of the market economy, in the bidding process, information is still being handled in the traditional way, which is inefficient, cumbersome and with a high error rate, resulting in a waste of resources. Therefore, only by strengthening the integration of enterprise information resources, unified management and bidding supervision, can the construction sector operate more appropriately, efficiently and safely. The bidding system has developed very rapidly in recent decades. In Britain, a special body has been established to oversee the bidding process. At the same time, the government has trained major personnel involved in the project in order to ensure that various budgets are utilized efficiently. In some major projects, the bidding and tendering system is in the charge of dozens of bidding and purchasing institutions established by the general office of the government in various industries and ministries. In EU countries, specific plans, guidelines and policies have been established, and regulations have been promulgated, to guide each country's development direction. These measures have made EU countries leaders in the field of automated office procedures. In order to ensure a reasonable

*zxz@hbue.edu.cn
†Corresponding author: dafengqi33@126.com
‡whutfj@126.com
§niyanling@hbue.edu.cn

and efficient bidding process, an important clause on bidding documents can be introduced regularly.

In today's highly developed society, the informationization of construction project bidding management has become an inevitable bidding trend. However, most of the work involved in tender registration is still done manually. Hence, a feasible solution is proposed that incorporates network information technology [1–3], the management of bidding work, and the integration and collaborative management of all kinds of enterprise information resources. Digital image processing is the use of computers or other digital devices to apply certain operations and processing [4–6] to digital images to achieve the desired purpose. In the 1980s, three-dimensional images were studied and began to be applied in numerous fields from space technology to small-scale electron microscopy processing, covering industry, agriculture, the military, medicine, aerospace and other domains [7]. It can adapt to various measurements, analysis and calculation. In the early stage of development, computer image processing technology was mainly used in industrial production and biomedical research, but was applied to only a small extent in agricultural engineering research. The specific method comprises mainly simple visual simulation where the object of study is extracted from the whole. Because of the complexity and large amount of information in digital images, the extraction of relevant information poses a significant challenge.

Pattern recognition is related to computer science, statistics, cybernetics, image processing, artificial intelligence and other disciplines. In the computer field, pattern recognition refers to the use of computers to identify the target entities represented or imitated by specific objective entities. Patterns refer to the information with spatial and temporal distribution obtained by observing specific objective entities; the whole pattern of isomorphic patterns or patterns in the same category is called a 'pattern class'. For example, in the field of remote sensing classification, it may refer to architecture, roads, shrubs, lawns and so on. The principle underlying 'pattern recognition' is to assign a pattern to its own pattern class according to a certain measurement method, measurement basis or measurement index. With the rapid development of sensor technology, computer application technology, automatic control technology and communication technology, pattern recognition is used in the processing of images derived from remote sensors. Pattern recognition is widely used to classify physical objects by means of a computer [8–11]. The computer application of pattern recognition to digital image processing simulates human recognition methods in order to recognize and classify digital images [12].

In regard to the bidding documents submitted for construction projects, the information they contain is quickly imported into the relevant systems. Combining the methods of image processing and pattern recognition, this paper proposes a bidding system platform for construction projects based on image processing and pattern recognition. The specific contributions of this paper are as follows:

(1) Firstly, image acquisition is performed on the construction project bidding documents, and the image is binarized.

(2) Secondly, the pre-processed image is recognized by a pattern recognition algorithm to obtain key information from the bidding documents.

(3) Finally, the key information is imported into the system platform to obtain useful information, which greatly improves the efficiency of staff. Relevant personnel were asked to use the proposed system, and the majority gave a very positive evaluation.

2. IMAGE PROCESSING AND PATTERN RECOGNITION

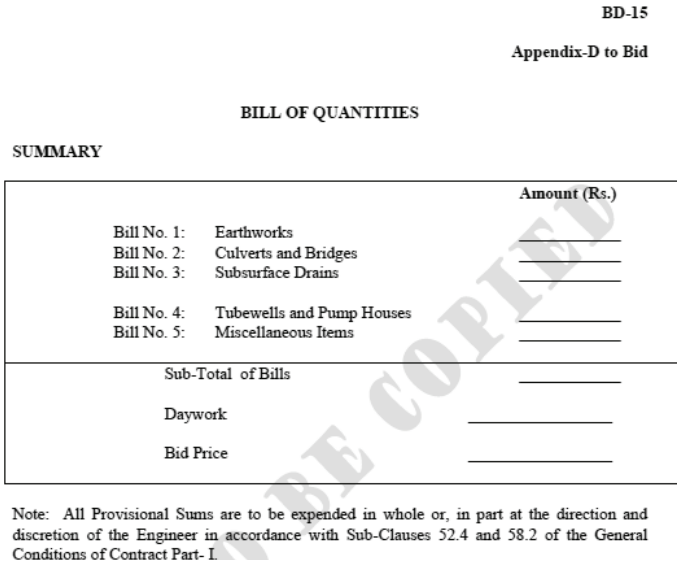
Because human perception of the world has a strong visual basis, images are a very important means for humans to obtain, express and transmit information. Digital image processing, that is, processing images by means of a computer, has a long history of development [13]. Digital image processing technology can help people understand the world more objectively and accurately. Human visual perception enables people to obtain more than three-quarters of the information present in their environment, and images and graphics are the conveyors of all visual information to the human eye. The pixel resolution is very high, and thousands of colors can be recognized, but in many cases, some images are blurred or even invisible to the human eye. Some image enhancement techniques can eliminate blurring so that a visible image becomes clearer. Pattern recognition refers to the process of processing and analyzing various forms of information collected by devices or sensors to characterize things or phenomena in order to describe, identify, classify and interpret collected things or phenomena. Also, they are an important component of artificial intelligence [14].

2.1 Image Pre-processing

The information in bidding documents collected directly by camera will be affected by illumination and camera itself, and may decrease the recognition detection rate. Therefore, image pre-processing is necessary before extracting information from bidding documents. This paper introduces two pre-processing methods: image gray processing and image binary processing.

2.1.1 Grayscale Processing

Preprocessed image is grayscale image [15–18]. A grayscale image is easier to process and detect at a later stage. It can improve detection efficiency and achieve better results. In image processing, it is very important to study the grayscale of the image. Most of the images taken by cameras are in color, and therefore contain a large amount of information. If the information in a bidding document contains a colored image, the subsequent processing time will be increased as will the amount of running memory. Therefore, the image must first be converted to gray. The purpose of gray processing is to convert the captured colored road image into a gray image. The RGB model has been established for color images. R, G and B represent the red, green and blue channels in the image. The range of pixels in color images ranges from 0 to $255 \times 255 \times 255$. In order to make each pixel only one of R, G and B, the gray scale only changes to 256 values. In this paper, the weighted average method is used to process gray level image. Different weighted values are


BD-15

Appendix-D to Bid

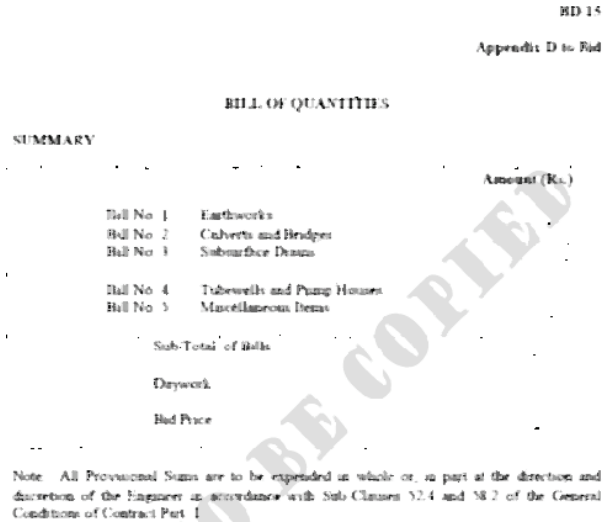
BILL OF QUANTITIES

SUMMARY

		Amount (Rs.)
Bill No. 1:	Earthworks	
Bill No. 2:	Culverts and Bridges	
Bill No. 3:	Subsurface Drains	
Bill No. 4:	Tubewells and Pump Houses	
Bill No. 5:	Miscellaneous Items	
	Sub-Total of Bills	
	Daywork	
	Bid Price	

Note: All Provisional Sums are to be expended in whole or, in part at the direction and discretion of the Engineer in accordance with Sub-Clauses 52.4 and 58.2 of the General Conditions of Contract Part- I.

(a) Grayscale processing


BD 15

Appendix D to Bid

BILL OF QUANTITIES

SUMMARY

		Amount (Rs.)
Bill No 1	Earthworks	
Bill No 2	Culverts and Bridges	
Bill No 3	Subsurface Drains	
Bill No 4	Tubewells and Pump Houses	
Bill No 5	Miscellaneous Items	
	Sub-Total of Bills	
	Daywork	
	Bid Price	

Note All Provisional Sums are to be expended in whole or, in part at the direction and discretion of the Engineer in accordance with Sub Clauses 52.4 and 58.2 of the General Conditions of Contract Part I.

(b)Wave filtering

Figure 1 Gray processing and filtering of a bidding document

added to R, G and B to obtain a gray level image. The weighted formula is as follows:

$$Gray = 0.299 * R + 0.587 * G - 0.114 * B \quad (1)$$

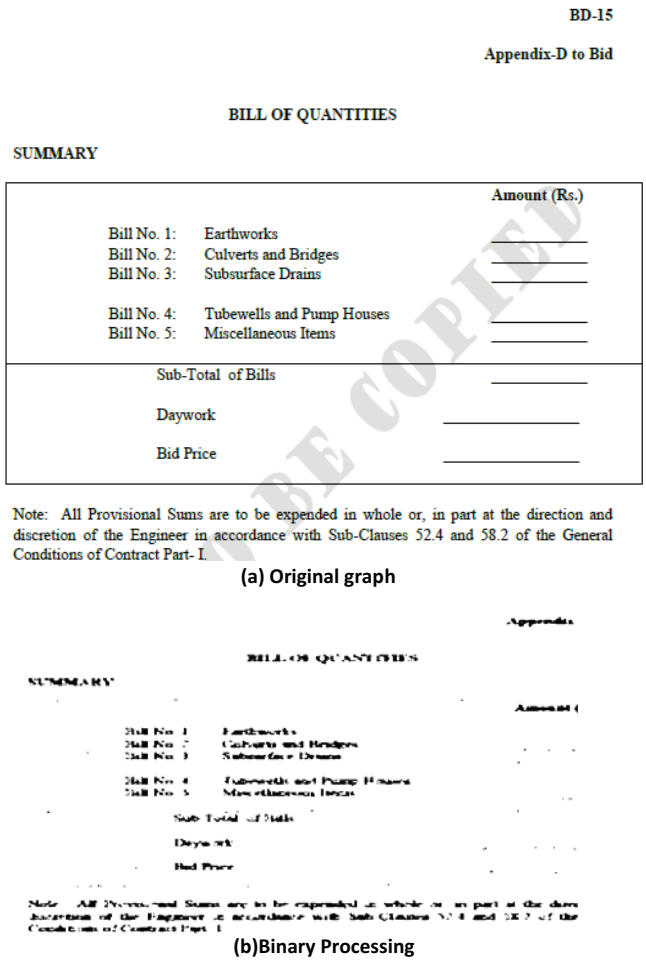
Because the photograph after shooting will be affected by factors such as light, shade and window reflection, it will produce useless noise, which may interfere with the recognition of patterns in bidding documents; hence, a great deal of useful information could remain undetected. In order to eliminate the influence of these noises, it is necessary to perform noise filtering on gray image [19]. In this paper, the average filtering method is used [20–22]. Then the overall pixels in the template are averaged and the original pixels are replaced with this average. For the pixels to be detected, a template consisting of several adjacent pixels is selected to find the average value, which is then used to replace the pixel value of the target pixel.

$$g(x, y) = \frac{1}{m} \sum f(x, y) \quad (2)$$

Following are the results of the graying and filtering of bidding documents:

2.1.2 Binary Processing

The process of grading the color image involves changing the gray level of each point in the image to 0 or 255, and the color image after gray processing has changed to a gray image. The method of binarizing the gray image requires finding the corresponding threshold using a specific algorithm, and comparing the gray level of each point in the image with the size of the threshold. According to the results of comparison, the pixel is divided into two categories: target and background. After binarization, the gray scale of the pixels in the image is only 0 and 255, and there is no other gray scale. In binarization processing, all points in an image whose gray level is greater than or equal to the threshold are defined as the target, and the gray level is set to 255; all points whose gray level is less than the threshold are defined as the background, and their gray level



BD-15

Appendix-D to Bid

BILL OF QUANTITIES

SUMMARY

		Amount (Rs.)
Bill No. 1:	Earthworks	_____
Bill No. 2:	Culverts and Bridges	_____
Bill No. 3:	Subsurface Drains	_____
Bill No. 4:	Tubewells and Pump Houses	_____
Bill No. 5:	Miscellaneous Items	_____
	Sub-Total of Bills	_____
	Daywork	_____
	Bid Price	_____

Note: All Provisional Sums are to be expended in whole or, in part at the direction and discretion of the Engineer in accordance with Sub-Clauses 52.4 and 58.2 of the General Conditions of Contract Part- I.

(a) Original graph

(b)Binary Processing

Figure 2 Binary processing of a bidding document

is defined as 0. The segmentation method of binarization is as follows:

$$g(x, y) = \begin{cases} 255 & f(x, y) \geq T \\ 0 & f(x, y) \leq T \end{cases} \tag{3}$$

In the formula, the pixel value at the coordinate (x, y) of the image is represented by $f(x, y)$, and the pixel value at the coordinate (x, y) of the image processed by the binarization method is represented by $g(x, y)$, T is the threshold value of binarization []. The basic process of binarization is as follows:

1) The image obtained by low-pass filtering is used to pre-process the image in order to reduce or eliminate noise.

2) The algorithm is used to determine the optimal threshold to ensure that the target area and the background area can be well separated by the demarcation line of the optimal threshold.

3) The gray scale of all points in the picture whose gray scale is larger than the calculated threshold is set to 255; the gray scale of all points whose gray scale is smaller than the threshold is set to 0. Therefore, the generated image can be used only in black and white. The image is divided into target area and non-target area, which completes the binarization of the image [23–26]. Figure 2 below shows the result of image binarization.

2.2 Pattern Recognition

After applying algorithms for grayscale and binarization in image preprocessing, we can extract features from the processed data. We then obtain the feature description we need, and then distinguish the features by means of pattern recognition, and then obtain the test results. After comparing with the standard range, we immediately establish procedure guidelines. Therefore, pattern detection and pattern recognition, as the core steps of image processing, have a vital impact on the detection results of the system.

Pattern recognition is a mathematical and statistical method used to classify information, processing and decision-making by a computer. The first step in applying pattern recognition is to create a pattern space. The so-called model space refers to the multi-dimensional space comprising many indicators affecting the target when examining objective phenomena, each of which represents a model parameter. The hypothesis consists of several events (samples), each of which has P characteristic parameters $(X_1, X_2, \cdots, X_P)$. It constitutes a P-dimensional pattern space, and the characteristic parameters of each event represent a pattern. The pattern recognition process is used to analyze the distribution characteristics of each pattern in multi-dimensional space, to divide the pattern space, and to recognize the clustering of various patterns. Pattern recognition helps people to make judgments, find rules or make decisions, and guide practical work or experimental research. Different patterns can be used

to identify different objects and different purposes of theory and methods. Common pattern recognition methods include statistical pattern recognition, grammatical pattern recognition, neural network pattern recognition, fuzzy pattern recognition and support vector machine [27]. The following is a summary of common pattern recognition theories and methods.

The analysis of image layout includes two methods: recharging method and bottom-up method. The recharging method starts from the macro direction of the image, and gradually divides the image into different modules by analyzing the global features of the image. Through repeated partitioning, the image is eventually divided into separate structural elements. Take the image processing of an ID card as an example. Firstly, the image region and text information region of the bid file are divided by using the prior knowledge of the image, and then the text region is divided. In the text region segmentation, the starting and ending positions of the character lines are first determined, and then the position of individual characters in each line is determined. The top-down method is effective for the relatively fixed character recognition of tender documents, but in a complex layout, it is difficult to accurately segment structural elements such as characters, tables and images because a large number of image details are ignored.

The bottom-up approach is based on the basic structural elements of the image, and gradually merges them into characters, images or tables by structural analysis of local elements. Then, by analyzing the positional relationship of characters, tables or images, row and column information in the image layout can be obtained. In order to extract the layout information, the structure of the image is analyzed step by step. In the bottom-up method, due to the large number of iterative operations, the calculation process is complex and the calculation speed is slow, so it is seldom used in practice. At present, a large number of text recognition methods based on optical characters mainly combine top-down method and bottom-up method to balance recognition speed and performance.

Pattern recognition is actually a classification problem involving the designation of an unknown pattern to one of the known categories. The membership principle is used as a recognition method. In the usual pattern recognition, the so-called pattern always has a clear, specific, clear and definite pattern. For example, when we want to recognize the image of cucumber disease in this experiment, its pattern is the standard cucumber disease sample image with typical symptoms. It is natural to classify it according to the principle of maximum degree of membership. This method, which directly determines the membership of a sample by calculating its degree of membership, is called the 'membership degree principle of pattern classification', and is also known as the 'direct method of fuzzy pattern classification'. The principles of membership are as follows:

Suppose U has a fuzzy subset in the universe $A_1, A_2, \cdots, A_n$, and there is a membership function $\mu_{A_i}(x)$ for each A_i, for any $x_0 \in U$, if there is:

$$\mu_{A_i}(x) = \max \mu_{A_1}(x_0), \mu_{A_2}(x_0), \cdots, \mu_{A_n}(x_0) \tag{4}$$

The principle of membership is obvious, but its classification effect depends heavily on the membership function of the known pattern class.

Fuzzy set theory is proposed to express the ambiguous aspects of human natural language and reasoning. Therefore, it is inevitable that there are some subjective factors in its application, such as the choice of membership function, the formation of fuzzy reasoning rules, fuzzy clustering and so on [28, 29]. Because of this, it can better add people's prior knowledge to an intelligent system. Recently, an increasing amount of evidence has shown that the fuzzy method is an effective alternative to the traditional model in the study of practical problems.

Most of the existing researchers usually use manual feature extraction based on manual design, such as SIFT, SURF, ORB and their extension algorithms. These manual features are effective for text classification and recognition, but there are some limitations in terms of three-dimensional object recognition. First, manual feature extraction relies mainly on past experience, which cannot easily be extended to many kinds of object recognition. Second, there are many parameter settings for extracting manual features, which require much feature construction and feature selection. The feature extraction method based on pattern recognition can avoid the above problems and has better applicability, as it can acquire more expressive features of images.

3. DESIGN OF BIDDING SYSTEM FOR CONSTRUCTION ENGINEERING BASED ON IMAGE PROCESSING AND PATTERN RECOGNITION

3.1 Requirement Analysis

The bidding for construction projects is a strong, professional field, so the bidding process must be carried out strictly in accordance with standard bidding procedures. Bidding management business consists of several parts. First, is user rights management. There are ten types of users, each of whom has different rights. These users are: provincial administrators, municipal tender office administrators, municipal tender announcement administrators, municipal credit archives administrators and county administrators. In addition, there are five types of enterprise users: construction units, construction units, survey and design units, supervision units and intermediary units. Provincial managers are responsible for appointing municipal recruitment managers, tender announcement managers and credit archives managers, and municipal tender office managers appoint county-level managers. Provincial staff are responsible for the supervision and management of the entire bidding process. The administrator of the Municipal Bidding Office is responsible for the allocation of level administrators, project construction, approval, bidding, bid evaluation and other work. At the municipal level, managers usually appoint administrative personnel at county level who are responsible for the corresponding work. The Municipal Credit Archives Manager is responsible for examining companies and their credit files in each city area. The manager of the Municipal Bidding Office mainly assists the Bidding Robbery Office in charge of the announcement of the bidding, the publication of the bidding documents and the setting of the price of commodity.

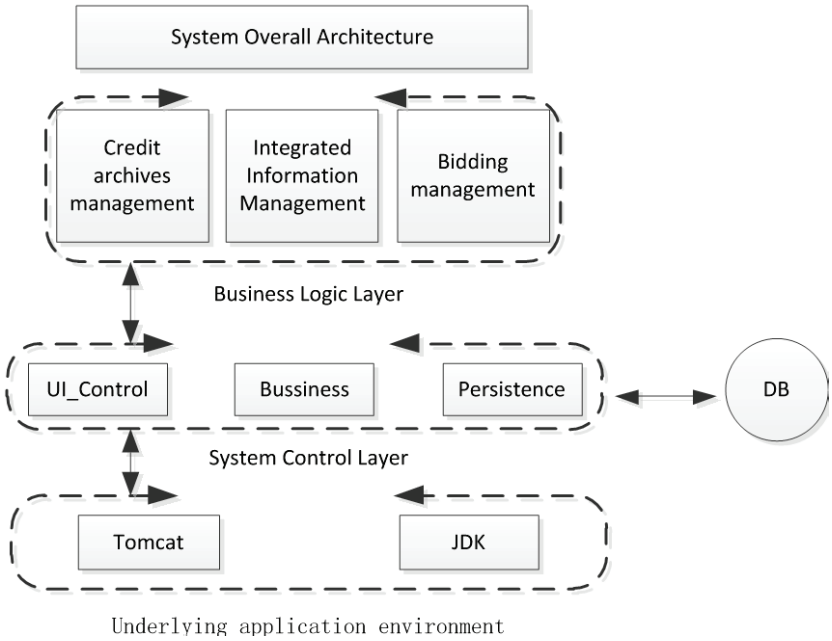


Figure 3 Overall System Architecture Diagram

County managers are responsible for the construction and company biddings for projects within their jurisdiction. Construction companies submit reports on their qualifications and performance. In regard to project management, information about the proposed project is issued to the construction company (i.e. the tendering unit) by the management personnel of the county or city tendering office. In order to ensure the accuracy, standardization and authenticity of information, it must be examined by the municipal authorities, specifically the administrator of the municipal tender office. Any false information must be dealt with seriously and deleted in time.

The management of bidding announcements is generally the responsibility of county-level bidding-office staff. After the project announcement has been issued, companies may apply for tender.

The registration of bids is mainly the responsibility of county-level staff. After the project and tender announcements, companies may apply for tender. The city credit archivist is responsible for scrutinizing company accounts, and for the modification, deletion and approval of company information. The management and integration of company information is generally the responsibility of the information publishers, who publicize and manage relevant laws, regulations and policies, conferences, and other relevant news. Moreover, they disseminate information about the project construction, tender applications and bids, the project itself, etc. In regard to security, personnel involved in managing the bidding must adhere to strict requirements for maintaining confidentiality of company and personnel information, bidding evaluation and data security.

System performance differentiates between data processing and information retrieval speed. Under normal network traffic conditions, data exchange and the response time of users at all levels and databases usually occur within 2–4 seconds. The system response time of a single operation on an operational interface is less than 10 seconds, and response time in a local area network is less than 3 seconds. Support multi-user concurrent access and data processing. The system runs continuously 24/7. The annual failure time is less than three days and the repair time is less than two hours.

System Maintainability Analysis: During processing operations, the system not only needs to meet the current business needs, but also must take into consideration the future technological development and changes in demand, as well as the expansion of functions, which can be easily implemented. To keep up with the current and long-term development needs of the whole construction industry credit system, the platform must be able to expand its functions according to the development needs.

3.2 System Design and Analysis

There are many users in the system, and their functions are different as well as overlapping. Different users cooperate to complete different business tasks of recruitment and investment. In order to correctly plan user rights and promote the development of functional modules, a user rights module is designed first. Then, according to the user's rights, abstract, classify and design a complex business process. Bidding management is subdivided into project construction, bidding management, bidding and evaluation management. The overall architecture of the system is shown in Figure 3.

3.3 System Function and Main Content

According to the bidding procedure of construction projects and the roles of different personnel involved in bidding, the bidding system is divided into four functional modules: invitation for bid (IFB), bidding, bid evaluation and government management.

The functions of each page of the bidding module are: bidding module homepage, bidders enter the homepage after login, and the homepage displays notification letters and item lists. Notification lists show information sent by other

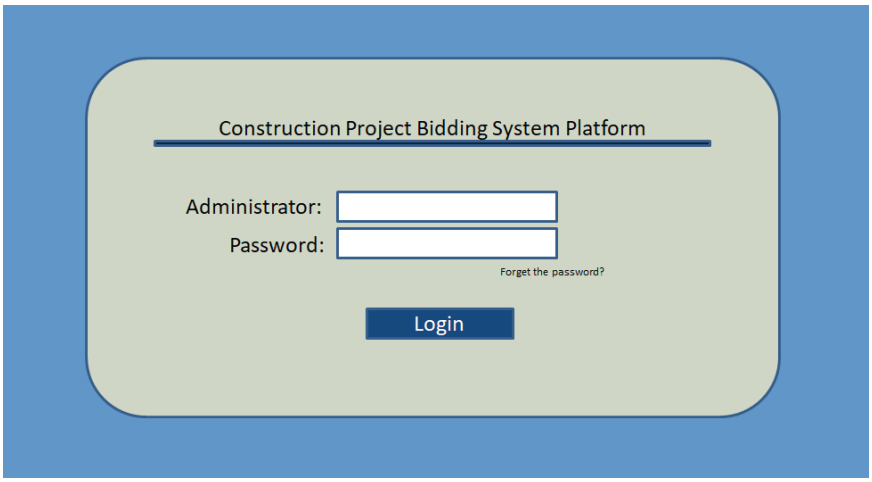


Figure 4 Login Interface of Platform System

relevant units, and project lists show the bidders' completed and unfinished projects. Users click on relevant links to view detailed information; for contract filing, the tenderer submits information on the filing method to the relevant government administrative departments; for bidding agency, the tenderer submits the information of the bidding agency to the relevant government administrative departments; bidding announcements are published, and the tenderer may download the standard format of the bidding announcement on this page. The industry reputation management module is used to examine the companies' qualifications and evaluation data, the results of which are sent to each applicant. Then, bidding documents and related information are sent to bidders. Tender documents are submitted to the government management departments. Companies who have met the qualification criteria ask and answer questions at the investigation site, and send the questions and answers on the survey website to the relevant units. Bid opening and evaluation show the bidding price of each bidder and provide links to the evaluation interface; the winning tenders are published, uploaded, and sent to each bidder; the tender information is filed, and the relevant bidding registration materials are sent to the government administration department; the construction contract is submitted, and the relevant materials of the construction contract are uploaded and sent to the government administration department.

The functions of each bidding page are as follows: on the bidding homepage, the bidder enters the homepage after login, and the homepage displays the list of notification letters and items. The letters show information sent by other relevant units, and a list of the bidders' completed and unfinished projects. Users click on the relevant links to view the details and submit the pre-qualification documents. When the tender documents are delivered, the bidder submits the tender documents to the tenderee, and the performance guarantee documents are submitted to the tenderee.

4. DISCUSSION

4.1 System Function and Main Content

A bid evaluation support system for construction projects is an information management website consisting of dynamic web pages. The system is written by Microsoft Visual Web Developer 2008 Express Edition development software, using Microsoft SQL Server 2005 to build database. The system adopts three design modes: UL display layer, BLL business logic layer and DLL data access layer. A dynamic Web interface allows human-computer interaction. The display layer is the page displayed by the browser and is the link between the contact person and the computer. This layer displays information to the user and records user operations. The business logic layer collects and transmits operation instructions through the display layer to determine the execution of the corresponding business logic, and transfers them to the data access layer when it needs to access the data source. After processing, the corresponding data is returned to the display layer, and the results are displayed to the user. Finally, human-computer interaction is achieved.

The presentation layer is the page displayed by the browser. The system is divided into four modules: IFB, bidding, bid evaluation and government management. Construction project IFB, bidding, bid evaluation and government management are conducted on the network. The business logic layer acquires data by calling SQL statements and calls the stored procedures in the database, and then returns to the presentation layer in the form of objects, thus realizing the function of data query and update. The business logic layer of the system mainly includes the following classes: project cost information query, bidder credit query, bidder quotation query, technical standard rating, business standard rating, etc.

The data layer is a data acquisition and interaction platform mainly concerned with the storage of procedures and data queries. This layer includes a historical project information category (including completed project information table), relevant units involved in the project information category (including: bidding unit information, bidding unit information), bidding project evaluation information category (i.e. bidder technical information table, bidder tender price information table, bidder credit list, etc.).

4.2 The Realization Effect Chart of Bidding System Platform

When users enter the system platform, they should first use the user identification interface. According to the different

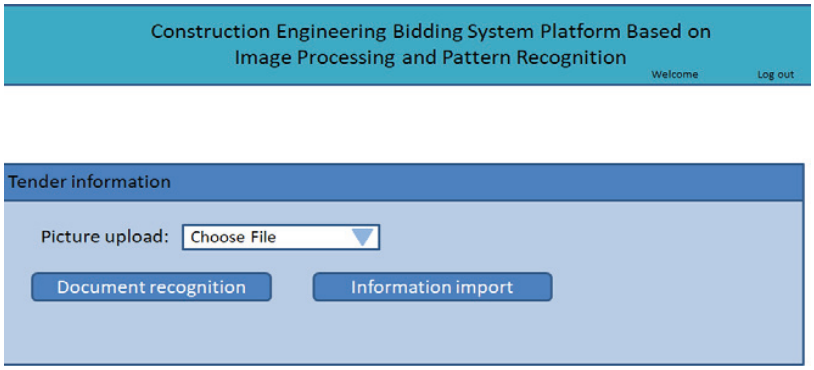


Figure 5 File Import System Interface

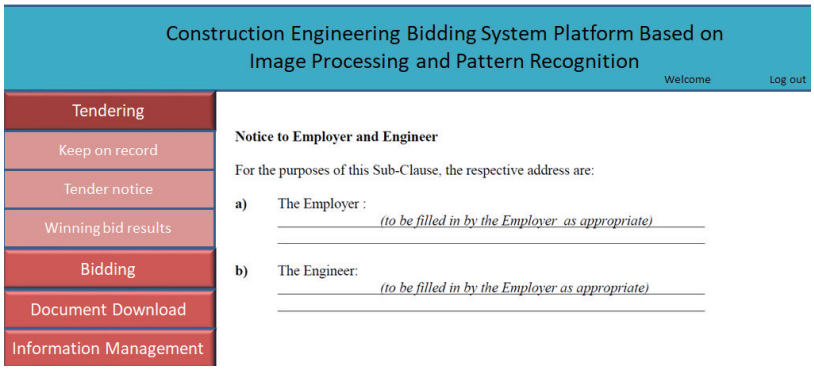


Figure 6 Binary processing

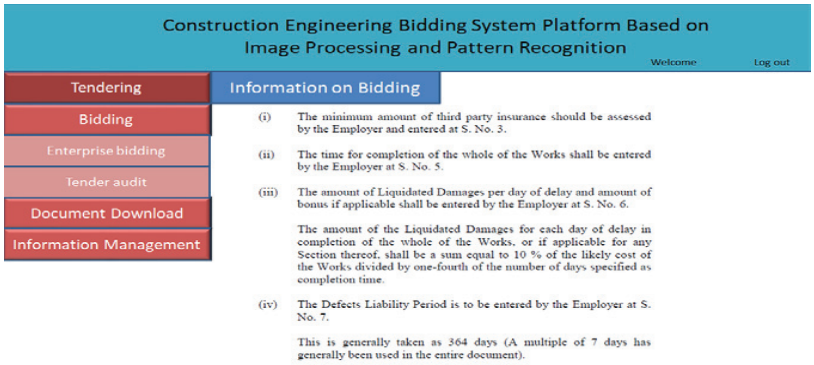


Figure 7 Generated information on Tenders

identities of users, the system automatically calls all functions and databases to which each user has rights. Users of different identity levels are shown different interfaces and functional modules when they enter the system. Each user can publish or query only the information within his own scope of authority. The system platform login interface is shown in Figure 5.

After login, the system will show an interface for importing documents. After importing the bidding documents into the system, the system will directly import the bidding information into the system through the internal algorithm image processing, and then through pattern recognition [30]. Then, the relevant information will be displayed in the system according to the bidding information. The import interface is shown in Figure 6.

Figure 7 below shows several matters requiring attention after obtaining relevant information. After the bidder logs in, he enters the home page, which shows the list of notification letters and the list of project items. The list of notification letters shows the information sent by other relevant units, while the list of projects shows the completed and unfinished projects of bidders. Users click on the relevant links to see the details.

Figure 8 shows some relevant information about the bidding pop-up.

5. TEST AND ANALYSIS OF PLATFORM IMPLEMENTATION EFFECT

The purpose is to satisfy the functional needs of users in the real environment, to achieve an accurate true service-oriented idea, and to operate the interface based on the framework system during the testing process, to see whether the user service needs are met, to achieve the expected functions, and then to analyze and evaluate the advantages and values of identification. First, a test is conducted to determine whether the throughput meets the requirements of the platform.

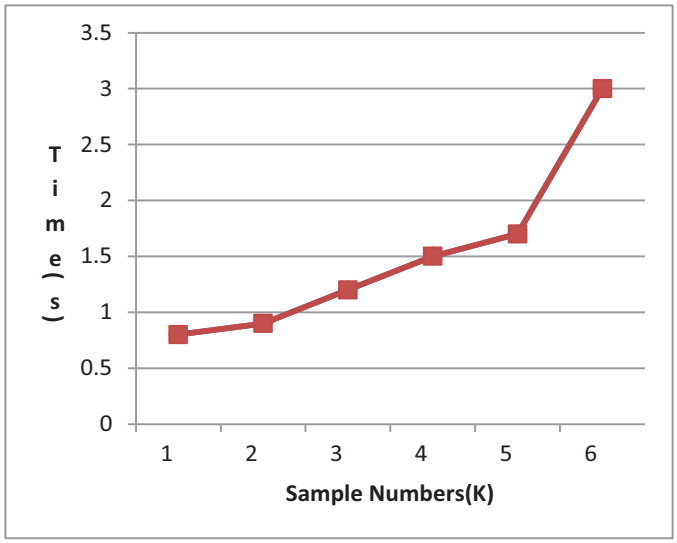


Figure 8 Response time of platforms with different number of users

6. CONCLUSION

In this paper, the business needs and overall objectives of the construction project bidding management system are analyzed in depth, and the system architecture and detailed functions are analyzed and elaborated. The bidding evaluation support system of construction project comprises a presentation layer, a business logic layer and a data layer, with the construction platform being based on image processing and pattern recognition. This platform is an improvement on the current bidding system, and has received the unanimous approval of relevant experts. This platform incorporates a very practical method for the identification and processing of bidding documents, which addresses the shortcomings of the conventional bidding system. The questionnaire survey results indicated that the majority of respondents (users) unanimously praised the design and suggested that it be applied in the future bidding for construction projects. Therefore, our bidding system platform has strong practical significance as it can greatly reduce the pressure on practitioners and improve their efficiency.

ACKNOWLEDGEMENTS

This work was supported by the PI Team Project of Hubei University of Economics (Intelligent Logistics and Application)

REFERENCES

1. Peng, L. I. U., Guangxian, L. Y. U., & Xianguo, K. A. N. G. (2017). Application of IEC 61968 Based Conformance Test Technology in Distribution Network Information Exchange. *Automation of Electric Power Systems*, 41(6), 142–146.
2. Bayar, M. F., Kurt, M., & Hasiloglu, M. A. (2018). Science and Technology Course in Educational Information Network: A Review on Videos. *Universal Journal of Educational Research*, 6(3), 413–420.
3. Polyantchikov, I., Srinivasa, A. B., Naikod, G. V., Tara, T., Kangilaski, T., & Shevtshenko, E. (2012, October). Enterprise architecture management-based framework for integration of SME into a collaborative network. In *Working Conference on Virtual Enterprises* (pp. 158–165). Springer, Berlin, Heidelberg.
4. Robertson, S., Azizpour, H., Smith, K., & Hartman, J. (2018). Digital image analysis in breast pathology—from image processing techniques to artificial intelligence. *Translational Research*, 194, 19–35.
5. Huang, J., Peng, Q., Hu, X., & Du, Y. (2017). A combined-alpha-shape-implicit-surface approach to generate 3D random concrete mesostructures via digital image processing, spectral representation, and point cloud. *Construction and Building Materials*, 143, 330–365.
6. Bahrami, M. E., Honarvar, M., & Ansari, K. (2017). Feasibility of using digital image processing and colorimetric measurements to estimate the physicochemical properties of raw cane sugars. *Sugar Tech*, 19(3), 305–316.
7. Sang-Bing Tsai, Yu-Cheng Lee & Jiann-Jong Guo. 2014. Using Modified Grey Forecasting Models to Forecast the Growth Trends of Green Materials. Proceedings of the Institution of Mechanical Engineers, Part B: *Journal of Engineering Manufacture, 228*(6), 931–940.
8. Ruxin, S., Guodong, W., Jianping, Z., & Lijun, N. I. (2017). Nirs-based pattern recognition of domestic flue-cured tobacco. *Tobacco Science & Technology,* 50(11), 39–47.
9. Lagorce, X., Orchard, G., Galluppi, F., Shi, B. E., & Benosman, R. B. (2016). Hots: a hierarchy of event-based time-surfaces for pattern recognition. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 39(7), 1346–1359.
10. Nabet, B. Y., Qiu, Y., Shabason, J. E., Wu, T. J., Yoon, T., Kim, B. C., ... & Minn, A. J. (2017). Exosome RNA unshielding couples stromal activation to pattern recognition receptor signaling in cancer. *Cell*, 170(2), 352–366.
11. Zerdoumi, S., Sabri, A. Q. M., Kamsin, A., Hashem, I. A. T., Gani, A., Hakak, S., ... & Chang, V. (2018). Image pattern recognition in big data: taxonomy and open challenges: survey. *Multimedia Tools and Applications*, 77(8), 10091–10121.
12. Hanxin Chen, Lu Fang, Dong Liang Fan, Wenjian Huang, Jinmin Huang, Chenghao Cao, Liu Yang, Yibin He and Li Zeng, Particle Swarm Optimization Algorithm with Mutation Operator for Particle Filter Noise Reduction in Mechanical Fault diagnosis, *International Journal of Pattern Recognition and Artificial Intelligence*.
13. Shan, P., & Lai, X. (2019) "Mesoscopic structure PFC similar to 2D model of soil rock mixture based on digital image",

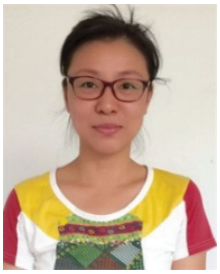
Journal of Visual Communication and Image Representation, 58, pp. 407–415.
14. Wang, Q., & Lu, P. (2019) "Research on Application of Artificial Intelligence in Computer Network Technology", *International Journal of Pattern Recognition and Artificial Intelligence*, 33(5), 1959015.
15. Sowmya, V., Govind, D., & Soman, K. P. (2017). Significance of incorporating chrominance information for effective color-to-grayscale image conversion. *Signal, Image and Video Processing*, 11(1), 129–136.
16. Chen, Q., Liao, Q., Jiang, Z. L., Fang, J., Yiu, S., Xi, G., ... & Liu, D. (2018, May). File Fragment Classification Using Grayscale Image Conversion and Deep Learning in Digital Forensics. In *2018 IEEE Security and Privacy Workshops (SPW)* (pp. 140–147). IEEE.
17. Sengupta, A., Roy, D., Mohanty, S. P., & Corcoran, P. (2017). A framework for hardware efficient reusable IP core for grayscale image CODEC. *IEEE Access*, 6, 871–882.
18. Hou, D., Zhang, W., Chen, K., Lin, S. J., & Yu, N. (2018). Reversible data hiding in color image with grayscale invariance. *IEEE Transactions on Circuits and Systems for Video Technology*, 29(2), 363–374.
19. Wang, J., Huang, J., Zhang, F., & Wang, W. (2019). Group sparse recovery in impulsive noise via alternating direction method of multipliers. Applied and Computational Harmonic Analysis.
20. Li, P., Liu, X., & Xiao, H. (2017). Quantum image weighted average filtering in spatial domain. *International Journal of Theoretical Physics*, 56(11), 3690–3716.
21. Bianchi, D., Lenauer, C., Betz, G., & Vernes, A. (2017). A wavelet filtering method for cumulative gamma spectroscopy used in wear measurements. *Applied Radiation and Isotopes*, 120, 51–59.
22. Li, W., Huyan, J., Tighe, S. L., Shao, N. N., & Sun, Z. Y. (2019). An innovative Primary Surface Profile-based three-dimensional pavement distress data filtering approach for optical instruments and tilted pavement model-related noise reduction. *Road Materials and Pavement Design*, 20(1), 132–150.
23. [18] Wu X, Saxena V. Dendritic-Inspired Processing Enables Bio-Plausible STDP in Compound Binary Synapses[J]. IEEE Transactions on Nanotechnology, 2018:1–1.
24. Mroszczyk, P., & Dudek, P. (2014). Trigger-wave asynchronous cellular logic array for fast binary image processing. *IEEE Transactions on Circuits and Systems I: Regular Papers*, 62(2), 497–506.
25. Arar, K., Mansouri, S., Benbouta, R., & Fedaoui, K. (2018). Processing and Characterization of a Copper Based Binary Alloy Achieved by Solid Phase Compaction and Sintering. In *International Journal of Engineering Research in Africa* (Vol. 38, pp. 1–8). Trans Tech Publications.
26. Ross-Howe, S., & Tizhoosh, H. R. (2018, July). The Effects of Image Pre-and Post-Processing, Wavelet Decomposition, and Local Binary Patterns on U-Nets for Skin Lesion Segmentation. In *2018 International Joint Conference on Neural Networks (IJCNN)* (pp. 1–8). IEEE.
27. Liu, X., Li, Y., & Wang, Q. (2018) "Multi-View Hierarchical Bidirectional Recurrent Neural Network for Depth Video Sequence Based Action Recognition", International Journal of Pattern Recognition and Artificial Intelligence, 32(10), 1850033.
28. Tsai, S. B., Chien M.F., Xue Y, Li L., et al. 2015. Using the Fuzzy DEMATEL to determine Environmental Performance: A Case of Printed Circuit Board Industry in Taiwan. Plos One 10(6): e0129153.
29. Kumar, M., Mao, Y., Wang, Y., Qiu, T., Chenggen, Y., & Zhang, W. (2017) "Fuzzy Theoretic Approach to Signals and Systems", Static Systems. Information Sciences, 418, pp. 668–702.
30. Guo, K. (2019) "Research on Location Selection Model of Distribution Network with Constrained Line Constraints Based on Genetic Algorithm", Neural Computing and Applications, 2019(1), pp. 1–11.

Author's introduction

Xianzhe Zhang: Ph.D. candidate, School of Civil Engineering and Architecture, Wuhan University of Technology. Associate Professor, School of Business Administration, Hubei University of Economics.

Sheng Zhou received a PhD from Wuhan Economics Academy, P.R. China. Now, she works in the School of Management, Wuhan Donghu University. Her research interests include management engineering and management technology.
E-mail: dafengqi33@126.com

Jun Fang: Professor, School of Civil Engineering and Architecture,
Wuhan University of Technology.



Yanling Ni: Associate Professor, School of Business Administration,
Hubei University of economics.