Designing an Online Re-examination System for Graduate Entrance Examination

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Abstract

The conventional on-site re-examination for graduate entrance examination has caused a large number of personnel flow and aggregation, for which the graduate entrance examination could not be implemented safely during the major disease outbreaks, making online re-examination the primary means of graduate entrance examination during the prevention and control epidemic. However, the application of the existing commercial platform for online re-examination has great security risks and instability. This paper arranged the workflow and process settings of each step in the conventional re-examination, analyzed the defects of the traditional software architecture, and first attempted to apply microservices architecture to online re-examination for graduate entrance examination. It took micro service as the core and splited various business functions. And an Online Re-examination System for graduate entrance examination was designed based on microservice architecture by using MySQL database and blockchain technology. Then tracking the system use, an evaluation system for the online re-examination graduate entrance examination is designed through scoring method. The research results show that the design of the online re-examination system for graduate entrance examination is reasonable. It realizes the requirements of the online re-examination for graduate entrance examination, reduces the coupling degree between the services, and solves the problem of data trace in the re-examination. Online Re-examination system can effectively ensure the orderly development of graduate recruitment during the epidemic period, improve the efficiency and fairness of graduate entrance examination, and significantly promote the network process standardization and informatization of graduate re-examination work.

Keywords*: Online Re-examination, microservice architecture, blockchain, evaluation system, Graduate Entrance Examination*

Ⅰ. Introduction

Issues of efficiency, fairness, and justice caused by the expansion of postgraduate enrollment scale have become increasingly prominent and have raised much public concern. Unified National Graduate Entrance Examination is composed of preliminary examination organized by the national examination authorities and re-examinations organized by colleges and universities. Re-examination is an integral part of the selection and admission process of graduate students [1] as a properly designed re-examination mode can ensure the health and safety of candidates while also guaranteeing a reasonable and fair admission system [2]. However, as conventional on-site re-examination for graduate entrance examination requires many people to gather and move within a small space, it cannot be implemented safely during major disease outbreaks, such as the COVID-19 pandemic. Therefore, online re-examination has become the primary means of graduate entrance examination during the prevention and control epidemic [3]. Re-examinations are generally organised and implemented by the secondary colleges of universities; this setup is currently the key to building the information technology system [4] for graduate student admissions, but it is also a blind spot. Since the way re-examinations are conducted has changed, its organisation, management, content, and evaluation system must also be reconstructed and optimised. Therefore, this paper arranges the

workflow and process settings of each step in the conventional re-examination as a first attempt to apply microservices architecture (MSA) [5] to online re-examination for graduate entrance examination. In particular, the advantages of loosely coupled and componentised MSA were utilised to design an efficient and appropriate online re-examination system for graduate entrance examination. An evaluation system for online re-examinations of graduate entrance examination was built in accordance with the usage of the system. As regards data security, the MySQL database and blockchain [6, 7] were combined. Given the high latency and low throughput of blockchain [8], part of the data was stored on the blockchain, which ensures that it is tamper-proof and allows for automated transactions [9]. Through this system design, this paper ensured the smooth and orderly implementation of re-examination during a disease outbreak and served as a way to explore methods for re-examination of graduate entrance examination. This paper addresses the shortfalls of conventional re-examination and provides a scientific basis for reforming the Unified National Graduate Entrance Examination.

Ⅱ. Requirement Analysis

The re-examination and admission procedure for colleges and universities mainly involves the following steps:

(1) Payment of fees: The payment step primarily involves automatically generating payment receipts and submitting invoice applications after the candidate has paid.

(2) Qualification review: The qualification review mainly reviews the candidate's residence identification card, academic degree certificate, academic registration verification results, student card, other application materials, and the candidate's qualifications.

(3) Written examination: The written examination includes two parts, one for professional courses and another for equivalent and interdisciplinary categories.

(4) Interview: The interview mainly assesses the candidate in terms of their ideological and political background, morality, discipline-specific knowledge and comprehension, and foreign language skills.

(5) Admission: The admission step includes the assessment and calculation of the candidate's performance in the re-examination, the first examination results, the calculation and ranking of the total score, and setting and adjusting the admission target.

(6) Determining the advisor: This step usually occurs after admission, where a two-way selection is made between students and advisors to determine the final admission list.

At present, some commercial platforms in China have some of these functions. However, the graduate student admission system is different from other systems and has higher requirements in terms of integrity, standardisation, security, stability, and fairness. This paper independently designed the operational process of an online re-examination system for graduate entrance examination. The flow chart of the system is shown in Fig 1.

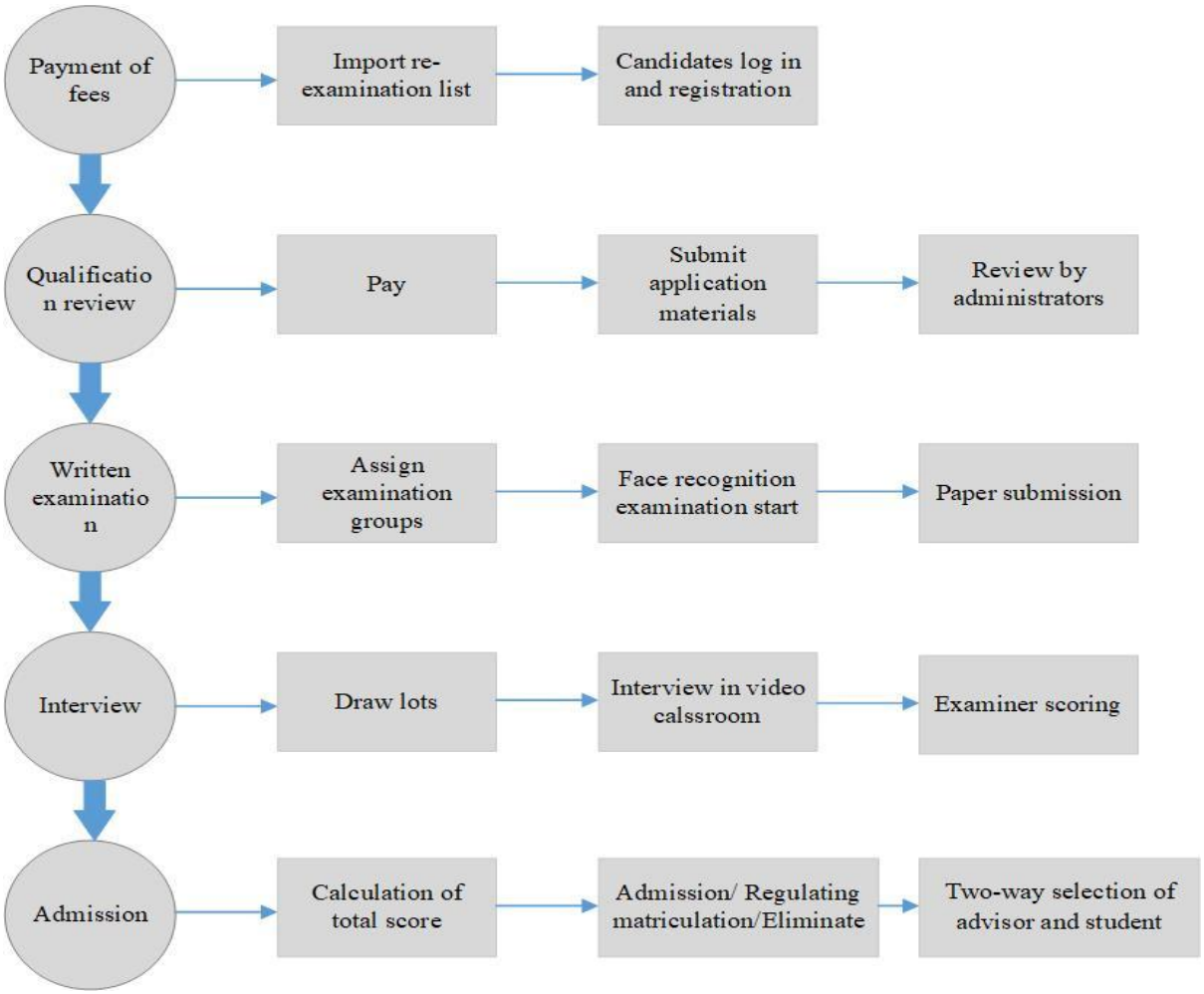

Fig 1: Flow chart of online re-examination system

Ⅲ. Operational Design

According to the operational requirements and the flow chart of the system, four main modules are needed. The first is the basic information module, which primarily includes user management, permission management, operational function management, candidate information management, and advisor information management. The system super administrator, which is the school-level manager, manages the system user account information, assigns different permissions to different roles, and executes any additions, deletions, and enquiries regarding the permission function. Also, the system super administrator can set different operational processes for different organisations or modify operational strategies according to policy changes. The college administrators may import the list of candidates who cleared the preliminary examination into the system and can review advisors' qualifications. The system automatically sends text messages to remind candidates to log in, register on the system, or change their passwords. At the same time, advisors can access personal information and enrolment plans.

The qualification review module includes the payment of fees, information submission, and material review. As a first step, candidates must log in and begin the material submission step, which includes a page for downloading the rules of the re-examination, system usage instructions, and relevant form templates. These forms include the Candidate Application Form, Candidate Re-examination Form, Expert Recommendation Letter, Ideological and Political Status Form, and Integrity Commitment Letter for Re-examination. Candidates are required to fill in the forms, sign and stamp the forms before scanning, and upload them in the format specified by the system. After

successfully uploading the personal materials, candidates can access the online re-examination fee payment step. This module should be coordinated with the university's financial system. After making a payment, an electronic downloadable invoice will be automatically generated for candidates. The college administrator may review the information of candidates who have submitted the materials and paid the fee, then assign them a corresponding examination team to review it.

The examination module mainly includes written examination group management, video interview room management, and invigilation management. After a candidate passes the qualification review, the system will automatically assign the candidate to different examination groups according to the major stated on their application and the written examination subjects that were selected. The system will then automatically send a message to remind candidates to enter the group examination room half an hour before the examination. The candidate would be required to undergo facial recognition before entering the group examination room, as this image will be compared with the photo used in the exam admission ticket on the system. After entering the examination room, the camera would automatically be turned on for the duration of the exam. The invigilator would then release the randomly drawn test bank at the designated time, which will appear on the candidate's screen. If the candidate withdraws from the system halfway through the examination due to interruptions, such as network issues, the test paper will be changed and the time restarted. The candidate will again be required to complete the examination paper and submit it within the allotted time. If there is a second interruption, the candidate will lose access to the group examination room for the written exam. After completing the written exam session, a lottery system will be used to determine the order in which candidates will enter the interview session. The system would remind candidates to enter the preparation group according to the pre-set interview time by order of the lottery results. At this point, the candidate will be invited to the online video classroom by the invigilator, and no other person will be permitted entry. The online video classroom allows users to share their screen to present a PowerPoint, start real-time video calls, and make video recordings. The invigilator manager is responsible for controlling access to the video classrooms, muting or unmuting participants, and recording the interview process. If a candidate withdraws from the classroom during the interview due to a network failure, the system will automatically re-allocate the remaining time and send a notification to the candidate to re-enter the video classroom. Suppose the examiner withdraws from the classroom during the interview process due to an unexpected event. In this case, the system will automatically cancel the examiner's score for that candidate to ensure fairness and impartiality.

The admission module includes score management, the ability to assign advisors, and admission management. After a candidate submits the examination paper, the system will automatically award a score according to the examination paper number and answer bank. The objective questions will be graded by a teacher that is assigned by the college administrator. Furthermore, the system has a scoring function embedded within it, such that each examiner provides a score in real-time during the online video interview. The system would automatically generate the final interview scores of the candidate according to the scoring method used. In addition, the system would automatically generate the total score of a candidate according to pre-set score calculation ratios. The college administrator can import the candidates' preliminary examination scores and the criteria for calculating the scores for re-examination, and can inquire and input statistics of the examination for all the candidates in their units. According to the admission indicators of each major in the admission plan, the system will sort the candidates based on their total scores and automatically make the admission decisions. Candidates may select advisors once their status has been changed to 'pending admission'. Candidates who are not admitted may either choose to end their attempts at admission or enter the transfer system to apply to other majors. When looking for an advisor, candidates may access the system to view advisors' curriculum vitae, select an advisor, and conduct one-on-one advisor-candidate video interviews during the specified time. After the video call, the advisor must indicate whether he/she is willing to accept the candidate. Candidates are also required to confirm the results of the interview within a specified time.

In addition to the main functions detailed above, the online review system for graduate entrance examination also

allows for sending notifications, private chats, group chats, sending and receiving documents, video classroom, lottery sorting, automated ID check, facial recognition, real-time video recording, payment of fees, and score calculation. It also includes a test question database, advisor database, invigilator database, and score database. The security and reliability of the results data are ensured by various measures such as data encryption, log collection, and specialised management.

Ⅳ. System Architecture Design

The typical architecture of traditional information management systems is generally monolithic [10], and includes Struts2, SpringMVC, and Mybatis. Monolithic structures have many drawbacks in terms of their maintenance, extension, and development. The current mainstream microservice architecture for the Internet has the following two advantages [11]. (1) The modules are highly autonomous, which allows for rapid changes and independent module updates in Internet applications. (2) The modules have high scalability, which allows for unpredictable users and dynamic resource allocation in Internet applications. As a result, microservices are gradually becoming the dominant architectural model for building Internet applications [12].

This paper is the first to attempt to apply microservice architecture to the graduate admission re-examination process. The specific features of software architecture technologies and their combination with the actual operational scenarios were considered. Separate front- and back-end architectures were adopted using the Spring Boot framework [13, 14], which is currently the most popular tool, as well as the Vue framework to improve the development efficiency of the system.

The microservices platform provided the basic environment for accessing and operating distributed services and offers the possibility of multi-technology integration for system construction through many public service components, while simultaneously ensuring that data specification and standards are met.

Microservices support each other at the data level and are loosely coupled in the operational logic. They are independent of each other and can be further integrated to perform more complex operations.

The online re-examination system for graduate entrance examination was designed using a multi-tier architecture, as shown in Fig 2. These include the presentation layer, application service layer, and data management layer.

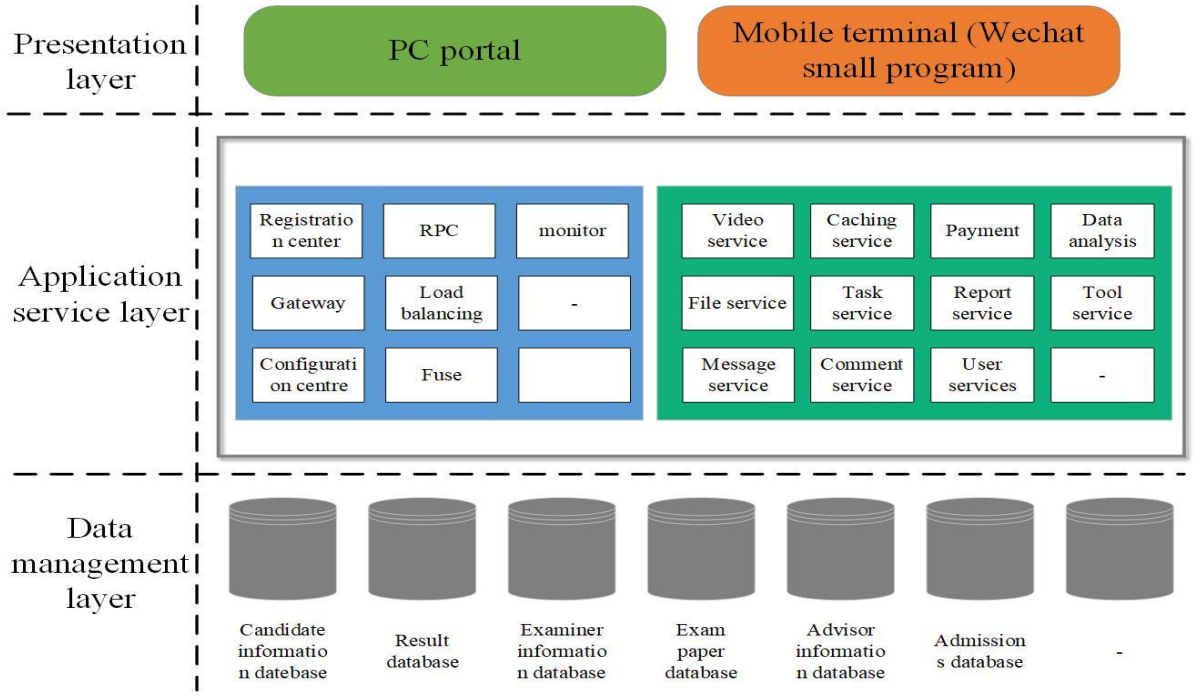

Fig 2: Architecture diagram of online re-examination system

The presentation layer is also referred to as the client layer and supports various access methods such as computer browsers, mobile browsers, WeChat, and mobile apps. The presentation layer can be connected to the application service layer through a lightweight communication protocol.

API Gateway: the API gateway, which is an integral part of the microservice architecture, provides a centralised strong control service for the serial APIs at the system boundary. In terms of design patterns, the API gateway implemented a façade and provided uniform access rules for the front-end. Furthermore, in this system, the API gateway provides features such as load balancing, service routing, and request filtering that isolated the outside from the inside, thus ensuring the security of back-end services.

The application service layer is the core of MSA and adopts a service-oriented approach to meet the functional requirements of different modules through calling and recombining ‘decentralised’ services. This layer was built with video chat microservices, file sending and receiving microservices, payment microservices, data analysis microservices, and messaging microservices.

The design of the data layers primarily involves seven data microservices: the re-examination candidate information database, the result database, the examiner information database, the exam paper database, the advisor information database, the admissions database, and the organisation information database for re-examination. In terms of data storage, the re-examination system adopted a combination of the MySQL database and blockchain to ensure the security of essential data such as grades and admission information. The information in the database mainly included candidate information, re-examination results, examiner information, admission information, and user access permissions. Storing all the data in the MySQL database can shorten the response time to user requests. Meanwhile, leveraging the traceability and non-tamperability of blockchain, the key information of the candidates involved in the examination can be stored on the blockchain after the examination results are released. All information and changes to information such as registration and the verification of candidates will be encrypted and recorded after being stored on the blockchain. In addition, student query results would be recorded on the blockchain and the hash value will be recorded, which is permanently valid.

The advantages of microservice architecture were mainly manifested in hardware requirements, project costs, development efficiency. The advantages were also manifested in the high cohesion, low coupling, scalability in system design, responsiveness to requirement changes, system upgrade efficiency, code reusability, non-functional requirements, and the manageability of risks. However, microservice architecture has brought about other problems and risks, such as increased system complexity, which may make it more difficult for developers to get started; therefore, it requires an understanding of the distributed system design to better develop and maintain microservices. In addition, the issues of calling distributed services, registry and discovery of services, distributed transactions between services, handling of data reports after database splitting, increased complexity of database queries, and consistency between distributed services also increased difficulties for system operation and management, which need to be prepared in advance when deploying a microservice architecture system.

The online re-examination system for graduate entrance examination was split into multiple smaller systems, thus making it more challenging to deploy, operate, and maintain. This issue was addressed by leveraging DevOps [15] and other approaches to automate its operation and maintenance. Microservices scale resource nodes for different operational modules on demand, and the system deploys multiple microservices and starts multiple runtime containers, which is slightly more complex than traditional architectures.

V. System Implementation

The above online re-examination system for graduate admissions can be applied flexibly to meet the needs of various operational processes such as interviews, written tests, and admissions. After logging in, users can submit information, pay fees online, complete written examinations in different categories, and conduct video interviews with advisors. The results can also be imported and calculated to determine which candidates are admitted. The back-end administrator may import the candidate list, debug the equipment for the written exam, and maintain the interview sessions, interview experts, results, and candidate information.

The whole system uses a microservice architecture and is divided into multiple application microservices including qualification reviews, fee payments, random lotteries, written examination rooms, video interviews, advisor management, and admission management. Each microservice is independently deployed and can be adapted to the rapidly changing application requirements.

The system adopts a microservices architecture that separates the front- and back-end, thus improving development efficiency and code maintainability. A Spring Cloud framework was used to implement back-end microservices, thus simplifying service configuration and improving fault tolerance and load balancing. In addition, Vue was used to implement the visual display of the front-end, thereby making it more scalable.

The back-end microservices section implemented the following functions:

(1) Service registry and discovery
A service registry was deployed and the service provider registered its call address to the service registry so that the service caller can be easily found. The service caller may find the address of the service needed in the service registry.

(2) Service load balancing
Service providers offered various services. As a result, load balancing allowed the service caller to connect to the appropriate service node, and the node selection process was transparent to the service caller.

(3) Service gateway
The service gateway was the only access point for service calls and implemented functions such as user authentication, dynamic routing, and load shedding.

(4) Configuration centre
Localised configuration information was registered with the configuration centre to enable package consistency across development, tests, and production environments and to facilitate package migration.

(5) Support platform
In a microservices architecture, systems became decentralised and are more difficult to develop, deploy, operate, and maintain. The support platform ensured that most of the work was automated, including continuous integration, health checks, and performance monitoring.

Front-end development:
Vue is a set of incremental frameworks for building user interfaces and is a JavaScript MVVM library that only focuses on the view layer. It uses a bottom-up incremental development design and aims to implement data binding and combine view components through APIs.

The model layer encapsulates the system's operational logic and data, which are implemented through each microservice. The data model layer (ViewModel) encapsulates the operational logic and state and was implemented using the Vue framework and JavaScript. The communication between the data model layer and the microservice was asynchronous. The data model layer requested data from the microservice with Axios, and the microservice returned the data in JSON format. The view layer encapsulates the UI and UI logic and implements the structure and view from the perspective of a user's screen.

Ⅵ. Testing

The complexity of testing systems with microservice architecture is high, and unit testing is essential to ensure the quality of the system and the efficiency of development and testing. The system was verified in terms of functionality and performance by combining test automation and other methods.

The web server of the test environment was Centos 7 with a 6-core Intel Xeon CPU 3204 chip at 1.90 GHz, 64 GB of RAM, 500 G of disk space, and 1000 M of bandwidth. Microservices related infrastructure environments included MySQL, Redis, RabbitMQ, Docker, Elasticsearch, and K8s.

The system adopted an agile iterative development and continuous delivery approach, with a release cycle every two weeks. The test automation during the development process were implemented in layers: a small number of unit tests at the bottom layer; API testing in the middle layer; and a part of contract testing on the top layer to ensure integration of the different services. In addition, there were manual exploratory tests, including some tests targeting the microservice features. The whole testing structure adopted a strategy similar to the honeycomb strategy. The production environment carried out error monitoring, user behaviour analysis, and user feedback collection to influence and guide the development and testing in the pre-production environment.

The testing of the main functions of the four modules, namely, the basic information module, qualification review module, examination module, and admission module, was carried out, and all the results met the system requirements. The detailed summary of bug resolution in the four versions is shown in Table 1. In versions V2.0 to V3.0, there was a significant increase in all types of bugs due to the interactive debugging of each functional module in the system. In versions V3.0 to V4.0, the various types of bugs were reduced steadily through the iterative version updates. As a result, the overall functions of the platform have been implemented with good system integrity. The remaining bugs did not affect the proper operation of the system or the functions, and the optimisation plan will subsequently be determined in combination with the operating conditions. In terms of system performance, according to the aggregated report data, the system with the microservice architecture supported the concurrent registration of 3000 users with good system stability and an average response time not

exceeding five seconds.

Table 1 Summary of bug resolution of different versions

Version ID	Fatal error	Serious error	General error	Slight error	Total
V1.0	2	234	277	170	683
V2.0	2	100	143	55	300
V3.0	30	237	306	75	648
V4.0	8	159	202	40	409
Total	42	730	928	340	2040

Ⅶ Online Re-examination Evaluation System

The online re-examination system assesses the professional capability, comprehensive quality, and innovation capacity of candidates. Compared with on-site re-examinations, the change in how the examination is conducted will inevitably lead to the reconstruction and optimisation of the content and evaluation system of the re-examination, which required the construction of an appropriate online re-examination evaluation system [16]. In this paper, 20 system users, including advisors, candidates, managers, and web developers, were employed to evaluate the system. In combination with their use of the system and the content of re-examinations, they used the scoring method and the 'weighted scoring model' to evaluate four assessment dimensions, namely, an online written test, a professional interview, an English interview, and a comprehensive quality examination with 16 indicators to comprehensively assess the online re-examination for candidates and determine the overall framework of the online re-examination evaluation system.

The specific methods were as follows. First, the rating indicator system was determined based on the content and process of graduate education and the re-examination, that is, four primary indicators and 16 secondary indicators. The users were then asked to fill out an evaluation weighted factor scoring form (see Table 2) and assign scores based on one-to-one comparisons of the four primary indicators. For example, A was compared with B. The evaluator would assign a score of 9 if he/she felt that A was very important compared to B, a score of 7 if A was slightly more important than B, 5 points if A was equally important to B, 3 points if A was less important than B, and 1 point if A was not important compared to B. For example, the online professional interview appeared to be relatively more important than the online written professional examination, so it was assigned a score of 7. The calculated values for this item from the scoring form of 20 users were averaged to obtain the weights of the four primary indicators and the 16 secondary indicators (see Table 3). This scoring method and the 'weighted scoring model' were used to obtain the online re-examination evaluation system for graduate entrance examination via the online re-examination system. The evaluation system was scientifically sound, representative, and typical, which means that it can be used as a reference for the reform of online re-examination for graduate entrance examination.

Table 2 Evaluation indicators of postgraduate online re-examination

Indicators of online re-examination	Indicators				Score
	Online written test	Professional interview	English interview	Comprehensive quality examination	
Online written test	×				
Professional interview		×			
English interview			×		
Comprehensive quality examination				×	

Table 3 Weight of indicators

Primary indicators	Weight	Secondary indicators	Weight
Online written test	0.14	Professional basic concepts	0.12
		Logical thinking ability	0.33
		Expression capability in writing	0.17
		Professional development ability	0.38
Professional interview	0.37	Professional knowledge structure	0.26
		Scientific research innovation ability	0.24
		Practical ability	0.15
		Comprehensive analysis ability	0.35
English interview	0.28	Professional English ability	0.38
		English translation ability	0.22
		Oral expression ability	0.37
		Daily application ability	0.13
Comprehensive quality examination	0.22	Undergraduate study	0.33
		Interest and specialty	0.17
		Timely response ability	0.38
		Cultivation and appearance	0.12

Ⅷ Conclusion

Given the urgent need to reform graduate entrance examination in the context of the COVID-19 pandemic, this paper proposed a scheme to build an online re-examination system for graduate entrance examination. By investigating the operational mode and workflow settings of each operational procedure of re-examination for graduate entrance examination, as well as analysing the traditional software architecture flaws, we propose using a mainstream microservice architecture for the online re-examination of graduate entrance examination. Each operational function was separated, and an online re-examination system for graduate entrance examination was designed based on a microservice architecture with microservices as the core. Finally, system use was tracked, and the scoring method was adopted to design an evaluation system for the online re-examination of graduate entrance examination. The following conclusions were obtained.

(1) All the online re-examination and admission functions proposed for graduate admissions were realised. A multi-layer architecture was adopted in the design and was divided into the presentation, application service, and data layers, thereby reducing the coupling between operations.

(2) The use of microservices architecture for development improved development efficiency and increased code maintainability. In addition, it allowed for the rapid deployment and adjustment of centralised high concurrency during interviews. The modular structure also facilitated subsequent functional scaling.

(3) Regarding data traceability during the re-examination process, the issue of data management in admission systems that use blockchain technology was addressed for the first time. To a large extent, the use of blockchain technology for data management ensured the fairness and impartiality of the admission process.

(4) The evaluation system for the online re-examination of graduate entrance examination was built based on feedback from different users through the scoring method, which accurately, scientifically, and fairly reflected the scientific rationality of said system.

In summary, this paper provided colleges and universities with a safe, efficient, scientific, and fair online

re-examination system for graduate entrance examination. This new line of development for the information technology services of graduate entrance examination fills the gap in the literature of online re-examination for Unified National Graduate Entrance Examination in China.

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