Hindawi
Advances in Multimedia
Volume 2023, Article ID 9768484, 1 page
https://doi.org/10.1155/2023/9768484

Retraction

Retracted: Application of Internet of Things Audio Technology Based on Parallel Storage System in Music Classroom

Advances in Multimedia

Received 12 December 2023; Accepted 12 December 2023; Published 13 December 2023

This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] H. Kai, “Application of Internet of Things Audio Technology Based on Parallel Storage System in Music Classroom,” *Advances in Multimedia*, vol. 2022, Article ID 5883238, 12 pages, 2022.

Hindawi
Advances in Multimedia
Volume 2022, Article ID 5883238, 12 pages
https://doi.org/10.1155/2022/5883238

Research Article

Application of Internet of Things Audio Technology Based on Parallel Storage System in Music Classroom

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Received 12 July 2022; Revised 26 July 2022; Accepted 5 August 2022; Published 14 September 2022

Academic Editor: Tao Zhou

In order to improve the effect of music classroom teaching, this paper combines the parallel storage system and the Internet of Things audio technology to construct a music education system to improve the effect of music education in colleges and universities. Moreover, this paper expounds a grid-free method for sparsity and parameter estimation from the model and mathematical principles and proposes a grid-free DOA method based on fast reconstruction of the T-matrix. This method is guaranteed to produce sparse parameter estimates. At the same time, the numerical simulation shows that the method has stable estimation performance as sparse and parameter estimation methods. In addition, this paper constructs a music classroom teaching system based on parallel storage system and Internet of Things audio technology. Through the experimental research, it can be seen that the parallel storage system and the Internet of Things audio technology has obvious application effect in the music classroom, which can effectively improve the teaching effect of the music classroom.

1. Introduction

Because of the curriculum setting and teaching goals of college students, many colleges and universities with strong practice majors also rarely have practical experience courses. In pure theoretical study, the practice of Western musical instruments cannot be displayed, so it is easy to form a boredom. The platform for college music students to show their style is also limited, and they cannot fully accumulate stage experience, thus affecting students' graduation and employment. For professional students, complete and systematic theoretical study is very important, and only with the support of the theory can they control different notes and complete their own creation [1].

For nonmusic students, if they want to learn about folk music, they are more likely to enter the campus through the "intangible cultural heritage" art organized by the school and the elegant art into the campus. Teachers and students of colleges of music can regularly invite local folk artists, scholars, and experts to carry out the dissemination of music culture and the study of skills in this area by regularly adopting the method of "going out and inviting in" [2]. It is also necessary to present the works adapted from local music culture through social activities and local activities, so that more people can know the charm of local music and generate higher social value. This kind of community performance activity will promote and motivate students to find inspiration, find props, explore local music culture, and display it in an ornamental and professional form [3]. Not only that, music education in local colleges and universities should be deeply integrated with community music education, and resources should be connected for mutual benefit. The community should provide a music practice platform for local colleges and universities, and local colleges should provide a theoretical learning environment for the community. And provide professional guidance for community music education and practice, make local culture more local, and allow students to better combine theoretical and practical learning [4].

Online teaching has indeed avoided the security crisis brought about by the epidemic and effectively controlled the losses of the institution itself, but the quality of online teaching really needs to be improved [5]. The specific manifestations are in the following aspects: the students' concentration will decrease, which will lead to laxity and neglect. The teacher's demonstration effect is poor, and the network transmission is delayed. The particularity of music is not reflected. Compared with other disciplines, the particularity of music education is reflected in emotion, performance, and creation [6]. Music education is aesthetic education. The first step in aesthetics is to perceive and feel. Only when students experience the emotions can they be displayed. Therefore, for more practical music courses, the sound quality, expressiveness, and emotional force of online courses are not as efficient as offline guidance [7].

The innovation of any teaching system and practice is inseparable from concepts. Concepts are the forerunner of the transformation of music education institutions and the premise and foundation of improving the quality of education and teaching. In this information age with rapid economic, social, and cultural advancement, traditional and rigid teaching concepts and methods can no longer meet the needs of the education industry [8]. Information is iteratively updated rapidly, and educational and teaching resources are rich and changeable. It is necessary for music teachers to look at problems from a developmental perspective and establish a life-long learning outlook on life and a teaching outlook with diverse personalities. The "postepidemic era" provides teachers with the opportunity to contact online education and also makes teachers who carry out online education realize the limitations. Therefore, music teachers should be prepared to learn and accept new things at any time and have strong adaptability and adaptability [9]. For online education, you should always be curious, learn network technology and equipment operation, and properly integrate your own music courses with online courses. The second is to learn to look at the problem dialectically. Any form of appearance must have its two sides. Carrying forward the favorable side of things, eliminating the dross side, promoting strengths, and avoiding weaknesses are the universal objective truth. Online education breaks the limitations of space, time, and number of people and brings great convenience to students' learning. However, it is an indisputable fact that students' concentration is reduced, teacher-student interaction is reduced, and learning effects are greatly reduced. Students' concentration can be improved through interaction, and students can also directly experience the delicate changes in music through personal demonstrations, but they are occasionally limited by the epidemic. In short, online education is convenient and fragmented, allowing learners to join learning anytime, anywhere; traditional education systems are efficient and conducive to learners' scientific and systematic training [10]. In addition, the concept of managers must be updated. Usually, management cannot be separated from three words: unity, concentration, and standard. This is consistent with the educational goal of large-scale training of standardized professionals in the industrial age. With the rise of the Internet and the advancement of the information age, the past educational concepts are no longer in line with today's development, and each teacher may create his own unique value. Therefore, it is necessary to build a teacher team based on the principle of "desynchronization, deunification, openness, and sharing" and encourage teachers to innovate music classrooms, carry out training related to network technology, and jointly create comprehensive, innovative, and exploratory music courses [11] .

College music courses should introduce more traditional folk music works and cultivate students' ability to appreciate traditional works. According to the viewpoints on the value of music education cited above, the cognitive ability of individuals to music needs to be gradually cultivated and improved through learning, so it is necessary to continuously deepen the auditory memory and auditory cognitive ability of traditional music works [12].

Students are guided to use their spare time to appreciate traditional music, or even create a collaborative mechanism between classroom teaching and campus art practice, and mobilize students' mouth, eyes, limbs, heart, and brain to participate in a series of operational activities such as singing, dancing, creation, evaluation., combining theory with practice, starting from different dimensions, effectively forming students' listening taste, and appreciating habits of traditional music [13].

In the selection of works, attention should be paid to selecting works that are short in length, novel in theme, rich in sound effects, and concise in melody lines and in different regions, styles, nationalities, periods, and genres, so that students can maintain a certain level of exposure to traditional music, auditory freshness, and positive emotional attitude to avoid aesthetic fatigue [14].

The cultivation of students' cultural self-confidence is inseparable from the shaping of historical views. Through the sorting out of music history, students can understand the rich texture of Chinese culture from the outside to the inside and integrate interdisciplinary knowledge in the process. Discussing and learning in different disciplines such as nature not only helps to shape students' broad cognitive horizons but also enables students to understand and master the development process of traditional culture through music learning, so as to comprehensively improve humanistic literacy and form an understanding of Chinese culture. *The goal of belief and identity in the spiritual core of culture* [15]. In order to make traditional music the main aesthetic object of college students, it is necessary to gradually cultivate their auditory interest in traditional music, so that these excellent traditional music classics change from unfamiliar to familiar in their minds and gradually form stable and positive emotional response and behavioral patterns [16].

Everything exists for a reason, and any action has a certain purpose. The essence of music education is mainly to educate people through musical works and music aesthetic education and finally achieve the effect of educating people, cultivating more high-quality talents that meet the needs of social development. Improve the overall quality of the people. At the current stage of development, the goal of socialist music education is relatively clear, and music education is regarded as one of the important means of aesthetic education, which can better serve the cultivation of talents with comprehensive development such as morality, intelligence, physique, and beauty [17]. He regards music education as a tool that "can educate people into beauty and kindness" and believes that music can change people's soul and quality. Since modern times, many countries have been studying music education. It also advocates the cultivation and development of human character. Music is not only cultivating musicians, promoting art, and demonstrating the value of art, but also serving the cultivation of people. Therefore, music education can be regarded as an important factor in the process of human growth and development [18].

This paper combines the parallel storage system and the Internet of Things audio technology to construct a music education system, improve the effect of music education in colleges and universities, and promote the reform of modern music.

2. Internet of Things Audio Technology

2.1. SPA Gridless Algorithm. We assume that $e(t)$, $t \in [N]$ is spatially white noise.

$$E\left[e(t_1)e^H(t_2)\right] = \text{diag}\ (\sigma)\delta_{t_1,t_2}. \tag{1}$$

Among them, $\sigma = [\sigma_1,\cdots,\sigma_M]^T \in \mathbb{R}_+^M$ is the variance parameter of the noise and δ_{t_1,t_2} is the delta function. If $t_1 = t_2$, the value is 1, otherwise the value is 0. We assume that the IoT music signal source and noise are uncorrelated with each other, and furthermore, the source IoT music signal is assumed to be spatially and temporally uncorrelated.

$$E\left[s(t_1)s^H(t_2)\right] = \text{diag}\ (p)\delta_{t_1,t_2}. \tag{2}$$

Among them, $P = [p_1,\cdots,p_M]^T \in \mathbb{R}_+^M$ represents the source power parameter. Under the above assumptions, the data snapshots $\{y_1,\cdots,y_M\}$ are uncorrelated with each other and have a covariance matrix.

$$R = E\left[y(t)y^H(t)\right] = A(\theta)\ \text{diag}\ (p)A^H(\theta) + \text{diag}\ (\sigma). \tag{3}$$

This chapter will study uniform and sparse linear arrays, so we will not repeat the array arrangement here. It is assumed that the array elements are evenly arranged at intervals of $\lambda/2$, where λ represents the wavelength of the IoT music signal source. For a ULA array with M array elements, the steering vector $a(\theta_k)$ of the k-th IoT music signal source has the form.

$$a(\theta_k) = \left[1, e^{j2\pi\theta_k},\cdots,e^{j2(M-1)\pi\theta_k}\right]^T. \tag{4}$$

Since a ULA array can detect at most M-1 IoT music sources, $K \leq M - 1$ is taken as a prior knowledge that the exact K value is unknown. The definition of the true covariance matrix R of the IoT music signal is given in the preamble section. $\widehat{R}$ represents the observation covariance matrix of the sample.

$$\widehat{R} = \frac{1}{N}YY^H. \tag{5}$$

When both $\widehat{R}$ and R are invertible, the covariance fitting criterion as formula (6) is considered for parameter estimation.

$$f_1(\theta,p,\sigma) = \left|\left|R^{-1/2}\left(\widehat{R} - R\right)\widehat{R}^{-1/2}\right|\right|_F^2. \tag{6}$$

In formula (6), R^{-1} is noisy, and $\widehat{R}^{-1}$ exists when the number of snapshots is larger than the array element ($N > M$). The minimization of the above formula is the maximum likelihood realization of the big snapshot. When $N < M$, $\widehat{R}$ is singular, and the above fitting criterion cannot be used continuously, so consider a new fitting criterion.

$$f_2(\theta,p,\sigma) = \left|\left|R^{-1/2}\left(\widehat{R} - R\right)\right|\right|_F^2. \tag{7}$$

These two criteria have been studied in some previous literature. The covariance fitting criterion of formula (7) exploits the assumption that IoT music signals are uncorrelated. This results in the observation covariance matrix $\widehat{R}$ having the formulation of formula (5) to show that the criterion is robust to source correlation. Therefore, this robustness is maintained in the proposed method utilizing the same criteria. Formula (7) is simplified to

$$f_1 = tr\left(R^{-1}\widehat{R}\right) + tr\left(\widehat{R}^{-1}R\right) - 2M. \tag{8}$$

Since the covariance matrix R expressed by formula (8) and formula (5) is nonlinear, it is very challenging to minimize f_1 when the parameters θ, P, and σ are relatively unknown. The true covariance matrix is estimated by reparameterization, that is, the covariance matrix R that needs to be fitted, and the definition matrix C is

$$C(\theta,p) = A(\theta)\ \text{diag}\ (p)A^H(\theta). \tag{9}$$

It is easy to conclude that $C \geq 0$, and rank $(C) = K \leq M - 1$. Further, the formula (10) can be obtained.

$$C_{jl} = \sum_{k=1}^{K} p_k a_j(\theta_k)\overline{a_j}(\theta_k) = \sum_{k=1}^{K} p_k e^{j2\pi(j-1)\theta_k}. \tag{10}$$

It can be obtained from formula (10) that C is a (Hermitian) Toeplitz matrix. We determine by M complex numbers that for some $u \in \mathbb{C}^M$ can be written as $C = T(u)$, where

$$T(u) = \begin{bmatrix} u_1 & u_2 & \cdots & u_M \\ \bar{u}_M & u_1 & \cdots & u_{M-1} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{u}_M & \bar{u}_{M-1} & \cdots & \bar{u}_1 \end{bmatrix}. \tag{11}$$

Next, we plan the SDP problem of positive semidefinite programming. From formula (11), a characterization such as formula (12) can be derived.

$$R(u,\sigma) = T(u) + \operatorname{diag}(\sigma). \tag{12}$$

The restatement of R in formula (12) and the minimization of f_1 in formula (8) is equivalent to

$$\begin{gathered}\min_{u,\{\sigma\succeq 0\}} tr\left(R^{-1}\widehat{R}\right) + tr\left(\widehat{R}^{-1}R\right),\\ \text{subject to } T(u) \geq 0.\end{gathered} \tag{13}$$

From the matrix knowledge $tr(AB) = tr(BA)$, the following equivalent derivation of formula (13) can be made:

$$\begin{gathered}\min_{u,\{\sigma\succeq 0\}} tr\left(R^{-1}\widehat{R}\right) + tr\left(\widehat{R}^{-1}R\right) \Leftrightarrow \min_{u,\{\sigma\succeq 0\}} tr\left(\widehat{R}^{1/2}R^{-1}\widehat{R}^{1/2}\right) + tr\left(\widehat{R}^{-1}R\right),\\ \text{subject to } T(u) \geq 0,\\ \Leftrightarrow \min_{X,u,\{\sigma\succeq 0\}} tr(X) + tr\left(\widehat{R}^{-1}R\right),\\ \text{subject to } T(u) \geq 0 \text{ and } X \geq \widehat{R}^{1/2}R^{-1}\widehat{R}^{1/2}.\end{gathered} \tag{14}$$

The constraint of formula (14) is further deduced into a formula to facilitate the solution of the positive semidefinite problem of programming. Three preliminaries are used in the derivation.

Knowledge 1: under the specific conditions of this paper, the inverse of the square root of the observed covariance matrix is equal to itself, that is

$$\widehat{R}^{1/2} = \widehat{R}^{1/2}. \tag{15}$$

Knowledge 2: if there are matrices A and B that satisfy $A \geq B$, then there is $B^{-1} \geq A^{-1}$.

Knowledge 3: if the matrix A is invertible, and A is a semipositive definite matrix, $A \geq 0$, and there is $C - B'A^{-1}B \geq 0$, then

$$\begin{pmatrix} A & B \\ B' & C \end{pmatrix} \geq 0. \tag{16}$$

Since knowledge 1 and knowledge 2 are basic common sense, only the conclusion of knowledge 3 is proved here.

When $T = \begin{pmatrix} I & -A^{1}B \\ 0 & I \end{pmatrix}$, there is $T'\begin{pmatrix} A & B \\ B' & C \end{pmatrix}T = \begin{pmatrix} A & 0 \\ 0 & C - B'A^{-1}B \end{pmatrix}$. From the properties of the matrix contract, it can be known that the semidefinite property of $\begin{pmatrix} A & B \\ B' & C \end{pmatrix}$ is the same as that of $\begin{pmatrix} A & 0 \\ 0 & C - B'A^{-1}B \end{pmatrix}$. Because $A \geq 0$, and $C - B'A^{-1}B \geq 0$, if $A = D'D$ and $C - B'A^{-1}B = E'E$ (D, E invertible), then there is $\begin{pmatrix} A & 0 \\ 0 & C - B'A^{-1}B \end{pmatrix} = \begin{pmatrix} D' & 0 \\ 0 & E' \end{pmatrix}\begin{pmatrix} D & 0 \\ 0 & E \end{pmatrix} = \begin{pmatrix} D & 0 \\ 0 & E \end{pmatrix}'\begin{pmatrix} D & 0 \\ 0 & E \end{pmatrix} = M'M$. It is obvious that M is invertible, so $\begin{pmatrix} A & 0 \\ 0 & C - B'A^{-1}B \end{pmatrix} \geq 0$, and $\begin{pmatrix} A & B \\ B' & C \end{pmatrix} \geq 0$. The proof is complete.

Therefore, formula (14) can be reconstrained as

$$\begin{gathered}\min_{X,u,\{\sigma\succeq 0\}} tr(X) + tr\left(R^{-1}R\right),\\ \text{subject to } \begin{bmatrix} X & R^{1/2} & 0 \\ R^{1/2} & R & 0 \\ 0 & 0 & T(u) \end{bmatrix} \geq 0.\end{gathered} \tag{17}$$

The problem in formula (17) can be expressed as a positive semidefinite programming problem and is therefore convex. The SDP problem can be solved by existing SDP solvers.

2.2. Rasterless Postprocessing for SPA. After obtaining an estimate of $\widehat{R}$ by CVX, the next task is to estimate the parameters θ, P, and σ from the covariance form expressed in formula (3). For this purpose, the observation covariance matrix $\widehat{R}$ is decomposed into the form.

$$\widehat{R} = T(\widehat{u}) + \operatorname{diag}(\widehat{\sigma}). \tag{18}$$

In formula (18), $\widehat{u}$ and $\widehat{\sigma}$ are the two parameters to be estimated in the IoT music signal processing, respectively, where $T(\widehat{u}) = A(\widehat{\theta}) \operatorname{diag}(\widehat{p})A^{H}(\widehat{\theta})$ is the estimated value of the covariance matrix of the IoT music signal defined in formula (9), and $\widehat{\sigma} \geq 0$is the estimated value of the noise covariance. Such $(\widehat{u}, \widehat{\sigma})$ always exists in the way given by the covariance matrix R that needs to be fitted, but it is usually not unique. In particular, for satisfying

$$T(u^* - \delta I) \geq 0, (\widehat{u}, \widehat{\sigma}) = \left(u^* - \begin{bmatrix} \bar{\delta} \\ 0 \end{bmatrix}, \sigma^* + \delta 1\right). \tag{19}$$

Any $\delta \geq -\min(\sigma^*)$ of formula (19) leads to one realization of the decomposition, and indeed all possible realizations are enumerated. The decomposition is made unique by exploiting prior knowledge of $K \leq M - 1$. From $K \leq M - 1$ it is concluded that $\operatorname{rank}(C) = K \leq M - 1$. The result δ of the direct decomposition is the eigenvalue of $T(u^*)$. Then by $T(u^*) - \delta I \geq 0$, we get

$$\delta = \lambda_{\min}(T(u^*)). \tag{20}$$

In the formula, $\lambda_{\min}(\bullet)$ is the smallest eigenvalue. Therefore, the decomposition is unique.

Postprocessing is used to separate the source and noise in the estimated covariance matrix so that the source part can be represented by as few sources as possible based on the principle of minimum description length. In fact, the concept of postprocessing has been studied in the literature, where R is the Toeplitz matrix, as in the case of equal $\{\sigma\}$. It is worth noting that postprocessing is very important in SPA, without it the final parameter estimates are often not unique. To make matters worse, the frequency estimates for SPA may no longer be sparse. To see this, assume that $T(u)$ has full rank (this is usually in the presence of noise). By choosing $\theta_1 \in [0, 1)$ arbitrarily, we make $p_1 < (a^H(\theta_1)T^{-1}(u)a(\theta_1))^{-1}$. The resulting residual term $T(u) - p_1 a(\theta_1)a^H(\theta_1) > 0$ still has a Toeplitz structure. θ_2 and p_2 can then be similarly chosen based on the residuals. This process can be repeated infinitely and results in infinitely long vectors θ and P.

The remaining task is to retrieve θ and a power estimate p for a given $T(u)$ and use it for a positive semidefinite Toeplitz matrix based on the following classical Vandermonde decomposition lemma.

Lemma 1. *Any positive semidefinite Toeplitz matrix* $T(u) \in \mathbb{C}^{M\times M}$ *can be expressed as*

$$T(u) = VPV^H. \tag{21}$$

Among them,

$$V = [a(\theta_1),\cdots,a(\theta_r)], \tag{22}$$

$$P = \operatorname{diag}\,(p_1,\cdots,p_r). \tag{23}$$

In the above formula, $\theta_j \in [0, 1)$, $p_j > 0$, and for $j \in [r]$, there is $r = \operatorname{rank}\,(T(u))$. Furthermore, if $r \le M - 1$, it means that the arrangement of elements for θ and P is unique.

From Lemma 1, it can be obtained that if $T(\hat{u})$ is given and $\operatorname{rank}(T(\hat{u}) \le M - 1)$, then the decomposed values of θ and p are uniquely determined. In practice, $\widehat{\theta}$ and $\widehat{p}$ can be estimated as follows:

$$T(\hat{u}) = A\left(\widehat{\theta}\right) \operatorname{diag}\,(\widehat{p}) A^H\left(\widehat{\theta}\right). \tag{24}$$

It's easy to get

$$\begin{bmatrix} A\left(\widehat{\theta}\right) \\ \bar{A}_{\{2,\cdots,M\}}\left(\widehat{\theta}\right) \end{bmatrix} p = \begin{bmatrix} \bar{\hat{u}} \\ \hat{u}_{\{2,\cdots,M\}} \end{bmatrix}. \tag{25}$$

Because $\widehat{p} \ge 0$, $\bar{A}_{\{2,\cdots,M\}}(\widehat{\theta})$ represents all but the first row of matrix $\bar{A}(\widehat{\theta})$ which is the complex conjugate of $A(\widehat{\theta})$. Therefore, this paper builds a system of 2 M-1 equations, which is linear in p and has length at most M-1, where each column of the coefficient matrix corresponds to a uniformly sampled sinusoid (after the arrangement of the rows). According to this lemma, we can program to solve $\widehat{\theta}$ and $\widehat{p}$ efficiently and finally get the result of DOA.

$$\theta_{DOA} = \arcsin\left(2\widehat{\theta}\right). \tag{26}$$

Since it is a half-wavelength array, there is the final DOA result of formula (26).

2.3. The Gridless DOA Algorithm for Fast Reconstruction of T-Matrix Proposed in This Paper. This paper proposes a new covariance fitting rule and then uses the postprocessing flow to obtain a new grid-free DOA estimation algorithm that is continuous in the spatial angle domain. The time complexity of the algorithm is better than that of the SPA algorithm, and at the same time, the same direction finding accuracy can be obtained. The specific numerical simulation is shown in the numerical simulation and analysis at the end of this section.

When the obtained rank of $T(u)$ is less than the number of array elements,

$$\operatorname{rank}\,(T(u)) \le M - 1. \tag{27}$$

The decomposition of $T(u)$ is unique. The DOA estimate of the incoming IoT music signal can be obtained using a postprocessing pipeline based on the Vandermonde decomposition theorem. Therefore, our task is to reconstruct the covariance matrix with low-rank properties from the sample covariance matrix. The so-called low-rank property is that the number of IoT music signal sources is less than the number of elements of the UM and array. The following minimization problem is reconstrained:

$$\begin{gathered} \min_u\ \operatorname{rank}\,[T(u)], \\ s.t. \begin{cases} \left|\left|\widehat{R} - T(u)\right|\right|_F \le \eta, \\ T(u) \ge 0. \end{cases} \end{gathered} \tag{28}$$

Formula (28) is an NP-hard problem and therefore basically impossible to solve in polynomial time. Moreover, a common alternative strategy is to convert rank constraints into trace constraints. Then, the following new constraint problem can be obtained.

$$\begin{gathered} \min_u \operatorname{trace}[T(u)], \\ s.t. \begin{cases} \left|\left|\widehat{R} - T(u)\right|\right|_F \le \eta, \\ T(u) \ge 0. \end{cases} \end{gathered} \tag{29}$$

Formula (29) is a positive semidefinite programming problem, which can be effectively solved by using the SDP solver to solve CVX or SeDuMi. After obtaining an estimate of $T(u)$, the DOA estimated parameters $\widehat{\theta}$ and $\widehat{p}$ can be easily obtained by using Lemma 1. Furthermore, the DOA

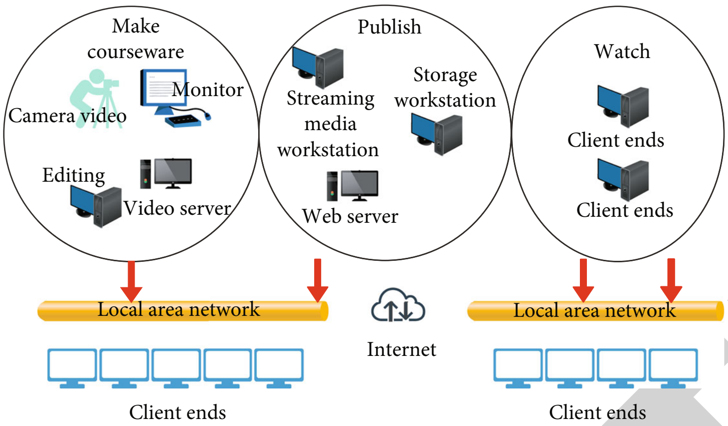


Figure 1: Topological structure of the system.

result $\theta_{DOA} = \arcsin(2\widehat{\theta})$ is obtained. In order to ensure that the true covariance matrix R is known accurately, there are following criteria for the selection of η.

$$\eta = \sqrt{M}\sigma. \tag{30}$$

When η is the above value, the precise covariance matrix R can be obtained from the limited snapshot data. Through Lemma 1, based on the Vandermonde decomposition of $T(u)$, the DOA parameter estimation can be accurately obtained. Next, we prove the correctness of this value. First, we introduce Lemma 2.

Lemma 2. *For a matrix* $A \in \mathbb{C}^{N\times N}$, *if*

$$tr[A] = \sqrt{N}\|A\|_F = \eta \tag{31}$$

Then, there is

$$A = \frac{\eta}{N}I. \tag{32}$$

The proof is as follows:

First, $A_{m,n}$ represents the $\{m, n\}$th element of matrix A, and $tr[A]$ and $\|A\|_F$ are represented in the following form:

$$\begin{aligned}
&[tr[A]]^2 = \left(\sum_{n=1}^{N} A_{n,n}\right)^2, \\
&N\|A\|_F^2 = N\left(\sum_{n=1}^{N} A_{n,n}^2\right) + N\left(\sum_{n=1}^{N}\sum_{m=1,m\neq n}^{N} A_{m,n}^2\right).
\end{aligned} \tag{33}$$

Obviously,

$$N\left(\sum_{n=1}^{N} A_{n,n}^2\right) \geq \left(\sum_{n=1}^{N} A_{n,n}\right)^2 \tag{34}$$

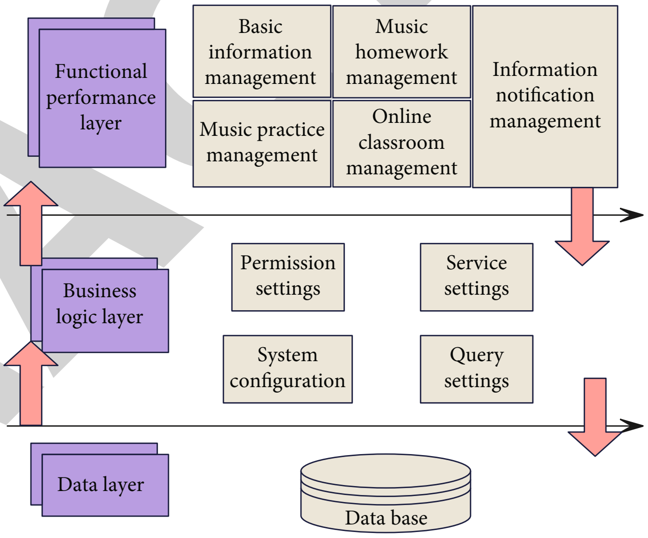


Figure 2: The architecture of the system.

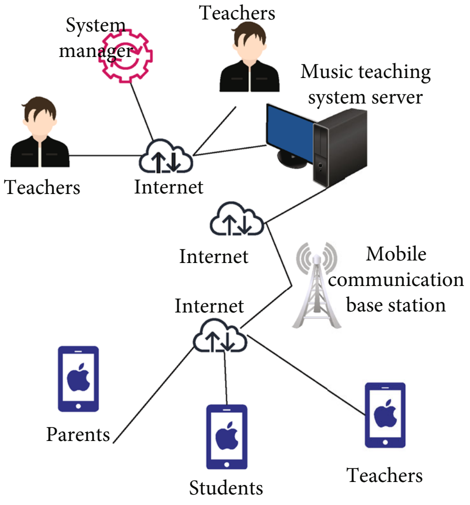
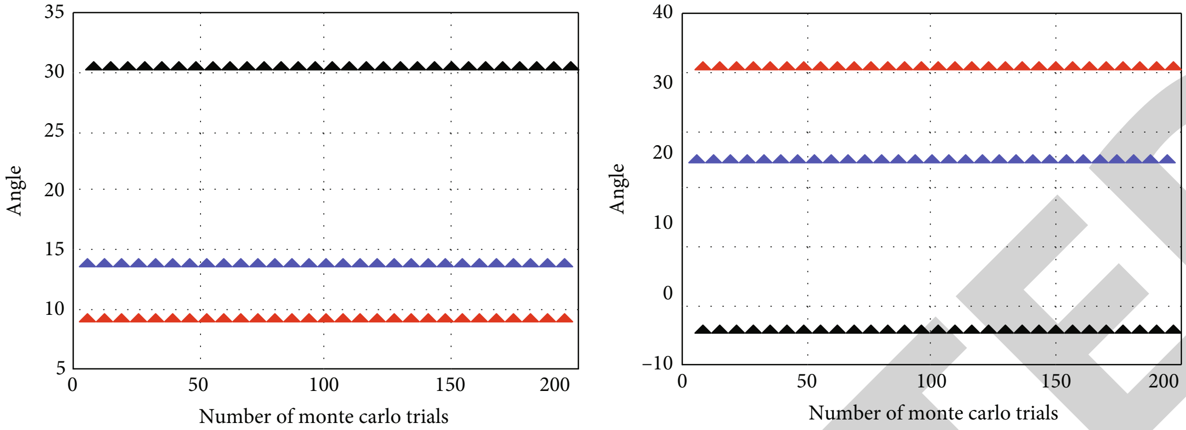


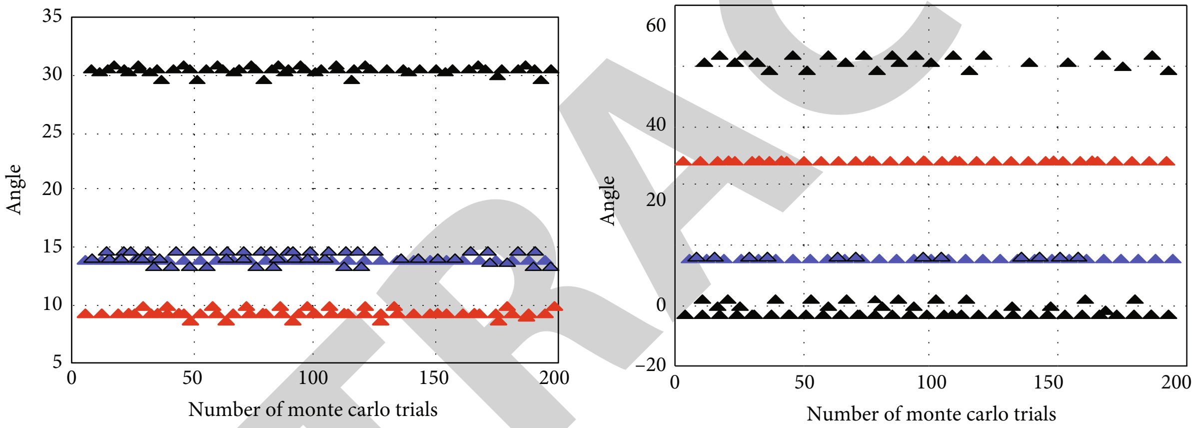
Figure 3: The physical structure of the system.



(a) Simulation results of the 100 fast-beat SPA algorithm

(b) Simulation results of the 100 fast-beat MUSIC algorithm

Figure 4: Comparison of DOA results of 100 snapshots.



(a) Simulation results of the 20 fast-beat SPA algorithm

(b) Simulation results of the 20 fast-beat MUSIC algorithm

Figure 5: Comparison of DOA results of 20 snapshots.

Therefore, it can be concluded that $A_{m,n} = 0\,(m \neq n)$. For example, A is a diagonal matrix. Further, the condition for the establishment of formula (34) is if and only if

$$A_{1,1} = A_{2,2} = \cdots = A_{N,N}. \tag{35}$$

At this time, the conclusion of equation (30) can be directly drawn. Next, we use Lemma 1 to prove the general case. First, we define

$$E = R - \widehat{T} = T + \sigma I - \widehat{T}. \tag{36}$$

In the formula, E represents the residual matrix, $\widehat{T}$ is the covariance matrix obtained by fitting, T is the true covariance matrix without noise, and I represents the identity matrix. From the above formula, we can get

$$tr[T + \sigma I] = tr\left[\widehat{T}\right] + tr[E]. \tag{37}$$

Since $tr[A] \leq \sqrt{N}||A||_F$ is a positive semidefinite matrix, there is $A \in \mathbb{C}^{N\times N}$. Therefore, we can get

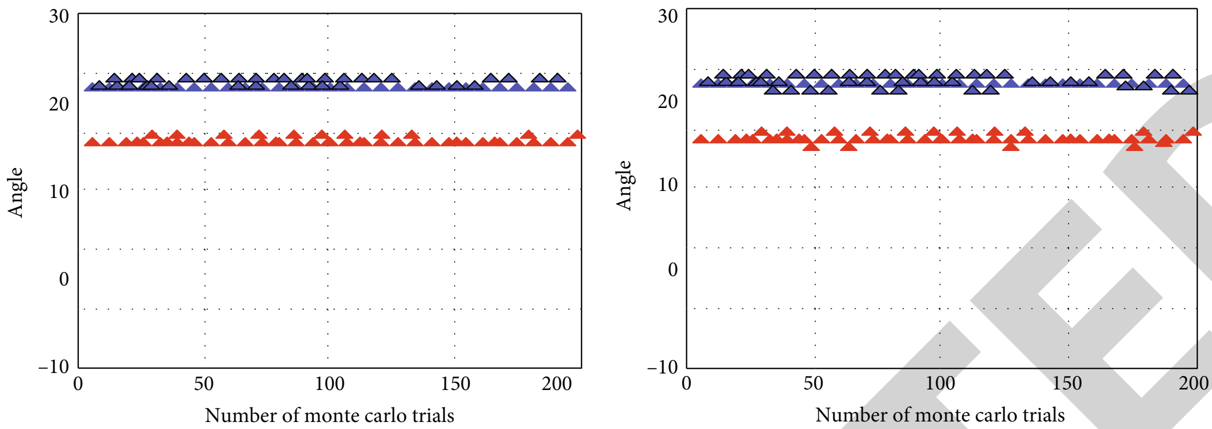
$$tr[T] + M\sigma \leq tr\left[\widehat{T}\right] + \sqrt{M}||E||_F \leq tr\left[\widehat{T}\right] + \sqrt{M}\eta. \tag{38}$$

When $\eta = \sqrt{M}\sigma$, the following conclusions can be drawn

$$tr[T] \leq tr\left[\widehat{T}\right] + M\sigma - M\sigma \leq tr\left[\widehat{T}\right]. \tag{39}$$

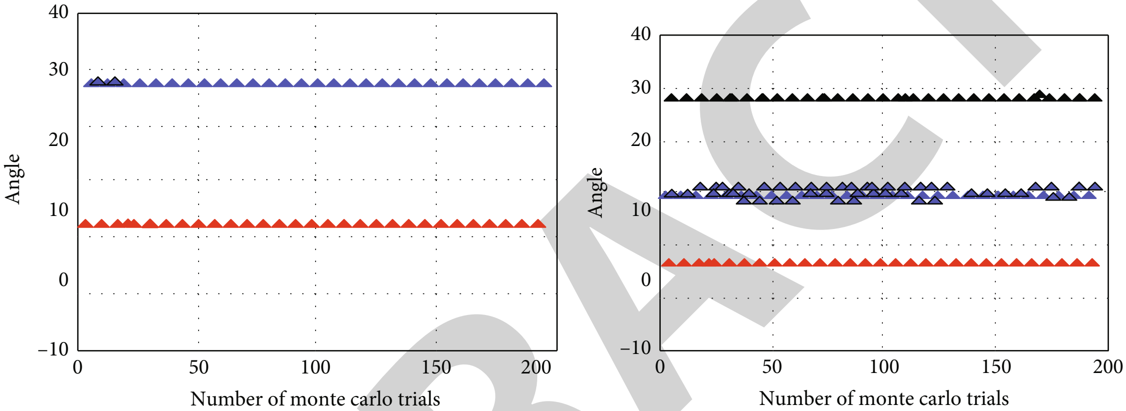
Since f is the solution of formula (28), $tr[T] \geq tr[\widehat{T}]$ can be obtained, and thus $tr[T] \geq tr[\widehat{T}]$ can be obtained. Substituting this formula into formula (37) and formula (38), we get

$$tr[E] = \sqrt{M}||E||_F = M\sigma. \tag{40}$$



(a) Dual-source (10°, 20°) simulation results

(b) Dual-source (12°, 18°) simulation results



(c) Dual-source (5°, 30°) simulation results

(d) Three sources (5°, 15°, 30°) simulation results

Figure 6: Multisource DOA simulation result of T-matrix fast reconstruction algorithm.

In Lemma 2, $E = \sigma l$ can be obtained. When it is substituted into formula (36), we get

$$\widehat{T} = T. \tag{41}$$

The proof is now complete. According to Lemma 1, the parameter estimation of DOA can be obtained using Vandermonde decomposition.

3. Music Classroom Teaching System Based on Parallel Storage System and Internet of Things Audio Technology

The system needs to consider the unstable factors of network bandwidth, the unsafe factors of Internet transmission, the shielding of users' illegal requests, and the friendliness of the user interface. With the rapid development of Internet technology and communication technology, the current popularity of AJAX makes more and more teaching systems tend to B/S design mode. By giving full play to the advantages of the B/S design mode, it can provide users with better services, give full play to the potential of Web applications, and provide the application depth and adaptability of this system in the Internet. It is necessary to consider adopting more advanced and mature system framework, server topology, system hierarchical design, and other rules, so that the system can meet the requirements of teachers and students for online music teaching. The system topology proposed in this paper is shown in Figure 1.

On the basis of system function analysis, complete the system design from the overall and functional modules. The overall design is the system outline design. Among them, the outline design includes the system architecture design and the physical structure design. The system architecture design completes the system architecture design from the perspective of independence of data, business logic, and functions. The structure of the system proposed in this paper is shown in Figure 2.

The system physical structure is described from the association of system physical network connection, server deployment, and user terminal, as shown in Figure 3.

4. Numerical Simulation and Analysis

This section compares the sparse and parametric grid-free method and the grid-based multiple IoT music signal feature classification method in the case of small snapshot data. In the experiment, the direction finding resolution of the uniform linear array is compared and analyzed. Moreover, a

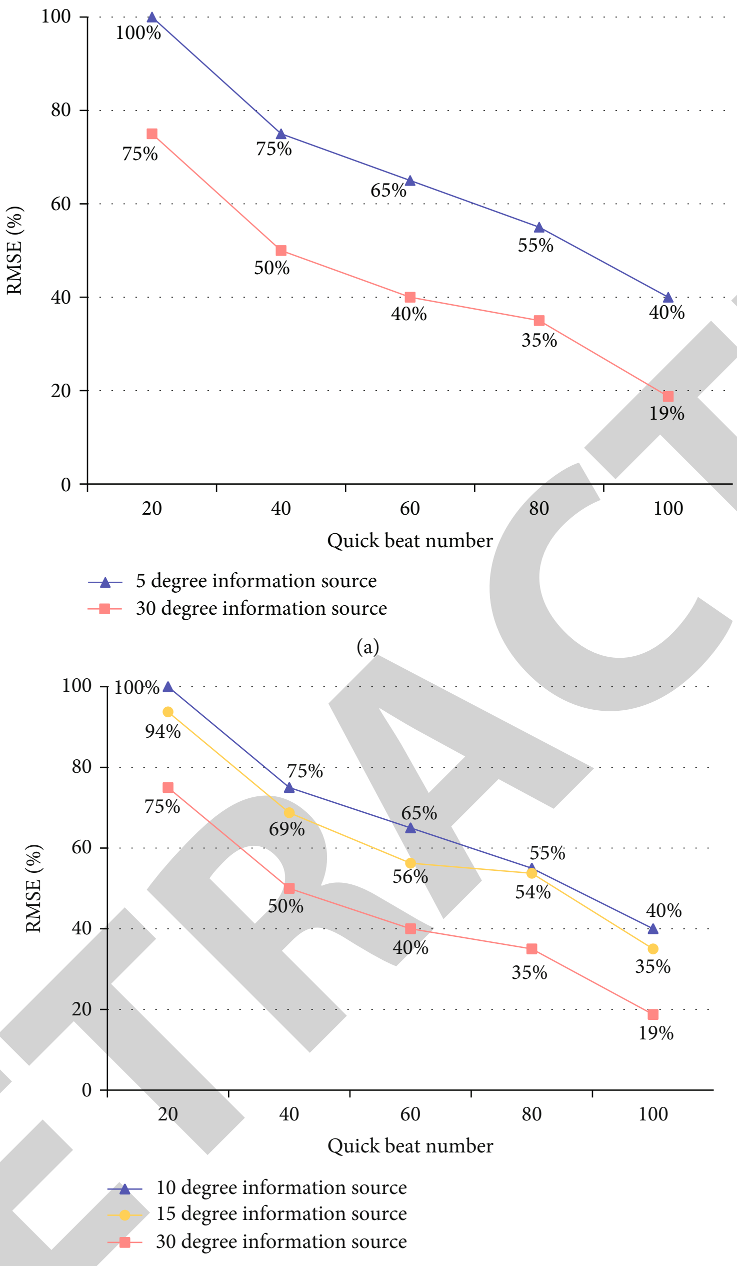


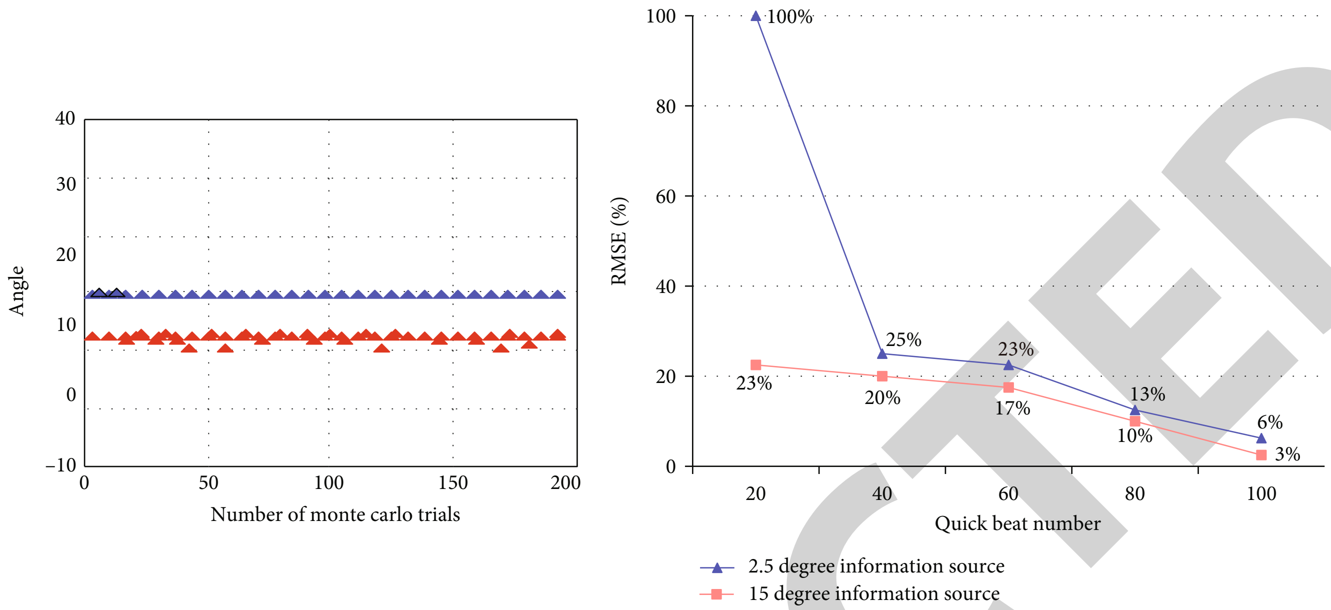
Figure 7: RMSE results of multiple sources with the number of snapshots for the T-matrix reconstruction algorithm.

sparse array is an arrangement of random draws from the uniform array introduced earlier.

The number of uniform linear array element sensors used in the simulation is 12, and the number of sparse array element sensors is 8. At the same time, there are 3 different IoT music sources in different places in the setup space. The corresponding spatial wave directions of the three sources are 12 degrees, 10 degrees, and 30 degrees, respectively. The signal-to-noise ratios of the three IoT music signal sources are 10 dB, 20 dB, and 5 dB, respectively. The number of data snapshots for the comparison simulation is 100 and 20, respectively. The number of Monte Carlo experiments is performed 200 times.

Under the simulation conditions set above, the MATLAB simulation results of DOA are shown in Figures 4 and 5.

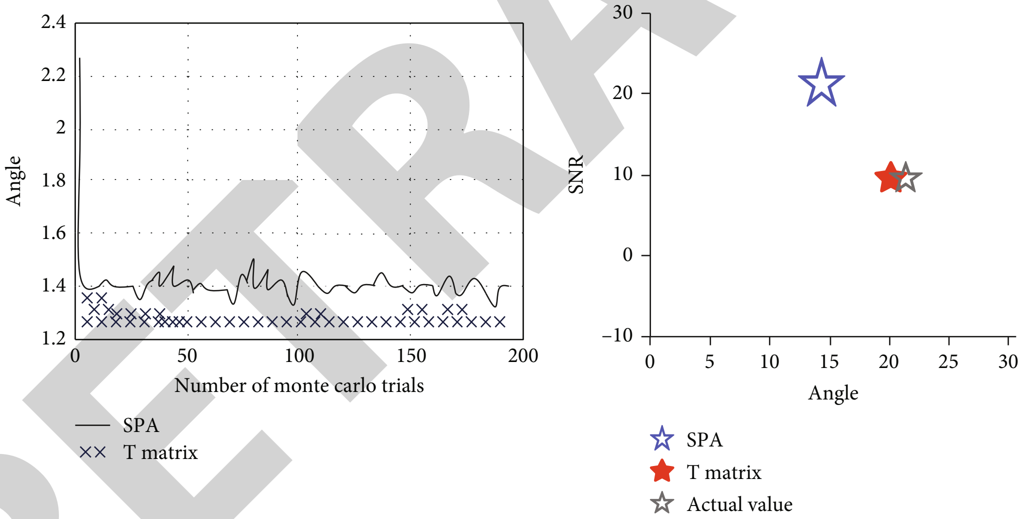
As can be seen from Figures 4 and 5, in the case of a small number of snapshots, the SPA algorithm can well distinguish three different IoT music signal sources, while the rough search MUSIC algorithm is completely wrong, and the result cannot be used. In the case of big snapshots, the performance of SPA is even better, while the MUSIC algorithm can estimate two adjacent angles at the correct angle, and the other angle fails to be completely estimated. The superiority of the SPA algorithm can be seen from the mean square error statistics table. Because MUSIC has an angle error, its mean square error is not counted.



(a) Strong and weak double signal angle results

(b) RMSE snap beats change

Figure 8: RMSE results DOA of strong and weak IoT music signals of T-matrix fast reconstruction algorithm.



(a) Time comparison of the two algorithms

(b) Performance comparison of the two algorithms

Figure 9: Comparison of running time and DOA accuracy between T-matrix reconstruction algorithm and SPA algorithm.

The simulation conditions are as follows: the number of elements of the uniform array is 12, the number of elements of the sparse linear array is 8, the number of signal sources is 2, and the signal-to-noise ratio is 10 dB and 15 dB, respectively. The number of Monte Carlo experiments is 200, and the number of snapshots is set to 100. Four groups of simulations are set up, and the source azimuth angles of each group are (10°, 20°), (12°, 18°), (5°, 30°), and (5°, 15°, 30°).

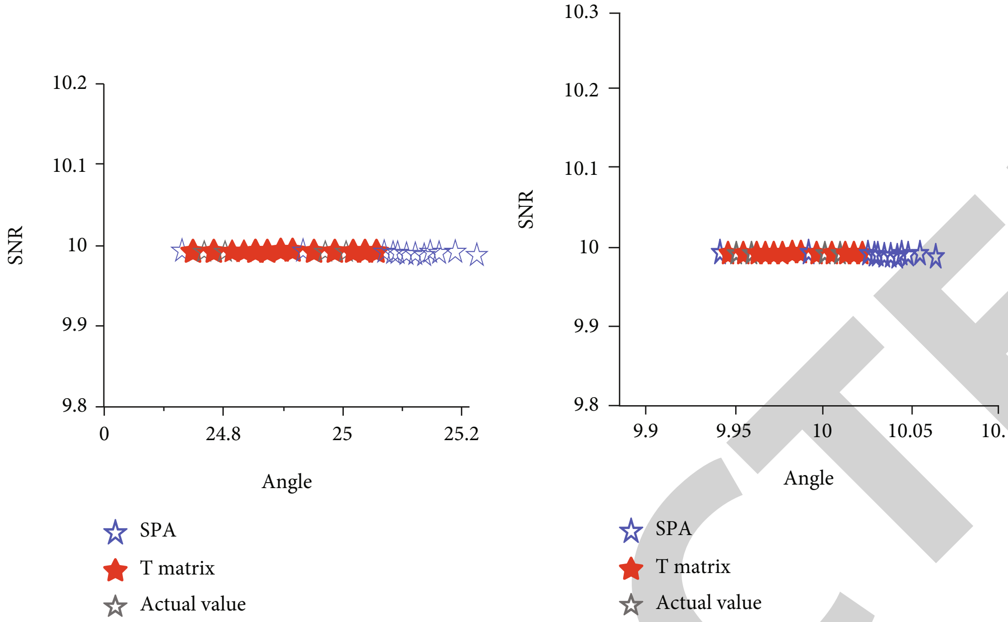
The DOA simulation results are shown in Figure 6.

From the multisource DOA simulation results in Figure 6, it can be seen that in the Monte Carlo experiment, the algorithm is stable and can adapt to the multisource situation.

At the same time, 200 Monte Carlo experiments are carried out under the conditions of different snapshot numbers by selecting two methods, two sources (5°, 30°) and three sources (5°, 15°, 30°). After that, the root mean square error (RMSE) of the DOA estimates was obtained.

The RMSE simulation results are shown in Figure 7.

As can be seen from Figure 7, the performance of the T-matrix reconstruction algorithm increases as the number of snapshots increases. In the multisource results, the 5° signal source tends to be above it because the signal-to-noise ratio



(a) 25° 10 dB scale fixation of signal comparison (b) 10° 20 dB scale fixation of signal comparison

Figure 10: Enlarged view of DOA accuracy of T-matrix reconstruction algorithm and SPA algorithm.

is 10 dB lower than that of the 30° signal source. The results of the three sources are also consistent with the trend of their signal-to-noise ratio settings.

In order to verify whether the method can adapt to the strong and weak IoT music signals that may exist in the actual environment with very different signal-to-noise ratios, 200 Monte Carlo experiments are carried out to verify it.

The simulation conditions of the strong and weak dual-source simulation are the same as before. The strength difference between the two signal sources is set to 20 dB, and the source positions are (2.5°, 15°). The simulation results are shown in Figure 8:

It can be seen from the simulation results in Figure 8(a) that the algorithm proposed in this paper can adapt to the strong and weak dual IoT music signals. The average of 200 DOA results of statistics is (2.4603°, 14.8421°), which can be seen from Figure 8(b) and further illustrates the effectiveness of this algorithm.

Next, the comparison of the time required by the T-matrix fast reconstruction algorithm proposed in this paper and the SPA algorithm is simulated. In the comparative experiment, the location of the IoT music signal source is (25°, 10 dB) and (10°, 20 dB), and all parameter settings are the same, as shown in Figures 9 and 10.

It can be seen from Figure 9(a) that when all the simulation conditions are set the same, the time of the fast T-matrix reconstruction algorithm in the Monte Carlo experiment is significantly shorter than the time required by the SPA algorithm. Moreover, statistics show that time has a 20% advantage. It can be seen from Figure 9(b) and Figure 10 that the T-matrix fast reconstruction algorithm and the SPA algorithm have the same performance, which shows that the method has strong practicability.

Table 1: Teaching effect evaluation of music classroom teaching system.

Num	Teaching evaluation	Num	Teaching evaluation	Num	Teaching evaluation
1	88.69	17	84.58	33	85.49
2	88.56	18	87.13	34	85.91
3	83.67	19	87.54	35	88.24
4	89.41	20	87.30	36	88.46
5	89.62	21	86.38	37	88.02
6	85.84	22	85.61	38	83.30
7	87.43	23	90.12	39	84.44
8	90.26	24	85.60	40	84.08
9	85.73	25	85.47	41	87.23
10	84.53	26	87.65	42	87.72
11	86.54	27	88.22	43	85.72
12	88.10	28	85.23	44	89.26
13	83.99	29	89.64	45	89.78
14	85.11	30	83.65	46	89.94
15	88.46	31	84.38	47	90.43
16	85.10	32	86.05	48	84.66

On the basis of the above research, the teaching effect of the music classroom teaching system proposed in this paper is evaluated, and the results are shown in Table 1.

It can be seen from the above research that the Internet of Things audio technology based on parallel storage system has obvious application effect in music classroom, which can effectively improve the effect of music classroom teaching.

5. Conclusion

Currently, traditional teaching forms are limited. The spread of the epidemic includes droplet transmission and contact transmission,, so traditional teaching has become a "good helper" for the epidemic. The reason is that in institutions, traditional courses require face-to-face communication between teachers and students in specific classrooms, which can easily cause droplet-doped viruses to spread indoors. Therefore, whenever the epidemic breaks out, for safety reasons, music institutions have to face the situation of temporarily suspending classes. Secondly, the online teaching form is limited. Some online courses in music institutions were born after the epidemic, or the epidemic forced the development of online courses. This paper combines the parallel storage system and the Internet of Things audio technology to build a music education system, improve the effect of music education in colleges and universities, and promote the reform of modern music. Through experimental research, it can be seen that the Internet of Things audio technology based on parallel storage system has obvious application effect in music classroom, which can effectively improve the effect of music classroom teaching.

Data Availability

The labeled dataset used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest

The author declares no competing interests.

Acknowledgments

This work was supported by Special Topic of Ideological and Political Work in Colleges and Universities in Zhejiang Philosophy and Social Science Planning in 2019, Project: Research on Curriculum ldeological and Political Construction Based on Supply-side Reform: Taking Art Education as an Example (No.19GXSZ48YB) and Shaoxing Philosophy and Social Sciences Research 13th Five Year Plan Key Topics for 2019, Project: Research on Ideological and Political Construction of Art Curriculum in the Perspective of Supply-side Reform (No: 135S020).

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