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Spectral Characteristic of Phosgene in External Electric Field

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Abstract: Phosgene is highly toxic, and it plays a role in the depletion of the ozone layer. The ground state geometric structure and spectral characteristic of phosgene in various external electric fields were calculated via the density-functional theory (DFT) and time-dependent density-functional theory (TDDFT) with the B3LYP/6-31+G(d) basis set. With external electric field, the structure of phosgene changed significantly. With increasing electric field, the bond lengths of 1C-3Cl and 1C-4Cl increased; the total energy and energy gap initially increased and then decreased, whereas the dipole moment initially decreased and then increased. Most of the IR vibrational frequencies were redshifted. The wavelength of the singlet excited state increased, reflecting a red shift, and the oscillator strengths of most transitions belonged to forbidden transitions. These results are of great significance for studying the dissociation of phosgene in external electric field.

Keywords: Density-functional theory; Phosgene; Spectrum characteristic; External electric field; Molecular dynamics

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1. Introduction

The ozone layer absorbs harmful ultraviolet solar radiation, and thus protects human and the environment. In 1974, Molina's team of American scientists reported that Freon has a destructive effect on the ozone layer [1]. In 1985, Farman's team confirmed this at an Antarctic station, but there was still controversy concerning its mode of action [2]. In 2009, Zhimin Lin's team reported on the dissociation rate of ClOOCl, which provided clear evidence [3]. Two-body dissociation generally occurs in the lower atmosphere, while multi-body dissociation often occurs in the higher atmosphere, such as the stratosphere. In external electric field, molecules undergo a series of physical and chemical changes [4-6], such as molecular chemical bond breaking, molecular orbital, crystallization, and changes in excitation spectra [7-9]. In order to study the formation mechanism of chlorine free-radicals and to understand the effects of chlorinated compounds on the atmosphere, it is necessary to study the ground state geometry and spectral characteristic of chloride under external electric field.

Phosgene is widely used in the chemical industry as a reagent in the production of polyurethane, dyes, rubber, plastics, pesticides, and so on; it is closely related to human lives. In 2021, Patrick Vossnacker's team searched for new synthesis methods of phosgene [10]; however, it is found susceptible to hydrolysis, which generates chlorine free radicals that have a destructive chain reaction with the ozone layer ($Cl + O_3 \rightarrow ClO + O$, $ClO + O_3 \rightarrow Cl + 2O_2$) [11]. At present, the research on phosgene mainly includes phosgene toxicity [12,13], treatment methods after phosgene poisoning [14,15], and more on the detection methods of phosgene [16-18]. Scholars have neglected the harm caused by phosgene when in use; therefore, the problem

of phosgene degradation needs to be solved urgently. At present, the only way to degrade phosgene is by thermal decomposition [19]. Degradation via external electric field is a new idea that has been applied to the study of halon molecules and methane derivatives [20-22]. The conditions required for electric field degradation are minimal, which is convenient for industrial applications. Due to the toxicity of phosgene, experimental research is inconvenient. Simultaneously, a theoretical study of phosgene in external electric field can reveal its ground-state geometric properties and spectral characteristic, which provide basic data for phosgene dissociation in external electric field. Therefore, it is of great significance to theoretically study the ground-state geometry properties and spectral characteristic of phosgene under the action of an external electric field. There have been few theoretical studies on the ground-state geometric properties and spectral characteristic of phosgene in external electric field.

Here, density-functional theory (DFT) and time-dependent density functional (TDDFT) with B3LYP/6-31+G(d) basis set were used to study the ground-state geometry properties and spectral characteristic of phosgene, providing a theoretical basis for its degradation via external electric fields (−0.05~0.05 a.u.). First, the ground-state geometry was optimized, including bond lengths, energy, dipole moment, energy-level distribution, and other physical parameters. Then, its infrared (IR) spectra were characterized. Those provided the basic parameters for the degradation of phosgene.

2. Theory and computational method

The Hamiltonian H of the phosgene molecular in applied electric field is given as follows:

$$H = H_0 + H_{\text{int}} \tag{1}$$

H_0 is the Hamiltonian without the electric field, and H_{int} is the Hamiltonian of the interaction between the electric field and the molecular system. Based on the dipole approximation, the interaction Hamiltonian between the molecular system and the electric field can be simplified as follows:

$$H_{\text{int}} = -\mu F \tag{2}$$

μ is the dipole moment of the molecule, and F is the electric field [6]. The convergence conditions were self-consistent-field and Davidson iterative. Self-consistent-field convergence involved a maximum force of ≤ 0.00045, a root-mean-square force of ≤ 0.0003, a maximum displacement of ≤ 0.0018, and a root-mean-square displacement of ≤ 0.001200. The Davidson iteration converged to the wave function variation of the n states, which was less than 0.001. All calculations were performed using the Gaussian 09 quantum computing software [23].

3. Results and discussion

3.1. Ground-state stable structure of phosgene

The calculated ground-state molecular structure model of phosgene was obtained at the lowest energy, as shown in **Figure 1**. Various methods and groups of phosgene molecules were optimized and calculated without an external electric field. The optimized vibrational frequencies were compared with the experimental values, as shown in **Table 1**. The vibrational frequencies obtained with the DFT B3LYP/6-31+G(d) basis set were consistent with the experimental data. Therefore, the DFT/B3LYP method and 6-31+G(d) basis set were also used for calculations of the molecule with an external electric field along the direction shown by the arrow in **Figure 1**.

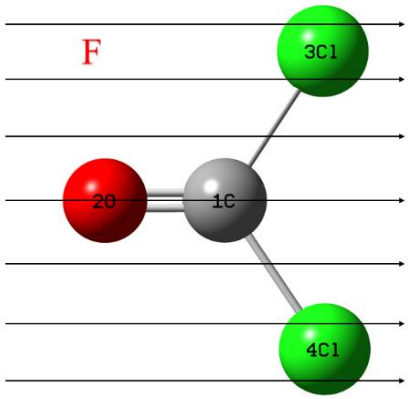

Figure 1. Stable structure of phosgene molecule

Table 1. Vibrational frequencies of phosgene molecule obtained using various methods

Vibration description	Calculated value/cm^{-1}					Experimental value/cm^{-1} [24]
	HF/6-31G	B3LYP/ 3-21G	B3LYP/ 6-31G	B3LYP/ 6-31+G(d)	B3LYP/ 6-311+G(d)	
CCl deform	303.96	264.99	279.58	303.44	302.09	285
CO deform	470.81	380.34	413.03	439.25	439.53	440
CCl s-str	560.16	468.77	505.73	561.56	555.54	567
C p-deform	605.04	530.79	542.64	583.43	585.56	580
CCl a-str	879.98	691.52	758.89	832.52	817.31	849
CO str	1961.88	1877.53	1819.36	1875.53	1879.37	1827

3.2. Geometric properties of phosgene in external electric field

The phosgene geometry structure was optimized for various external electric fields (−0.05~0.05 a.u.), which had significant effects.

3.2.1. Bond length

The effect on the bond length of phosgene in various electric fields is shown in **Figure 2**. The bond lengths of 1C-3Cl and 1C-4Cl increased with the electric field and were equivalent. In contrast, the 1C-2O bond length decreased with increasing electric field. The changes in the bond-length with electric field were attributed to the changes in the internal electric field [25]. With increasing external electric field, the charge transfer decreased the electric field, and the Coulomb forces became weaker between the 1C and the 3Cl atoms as well as the 1C and 4Cl atoms, decreasing the bond energies. Therefore, the 1C-3Cl and 1C-4Cl bond lengths increased, and their bond energies became weaker, easily breaking via the electric field. In contrast, with the external field, the 1C-2O bond was completely opposite, in which the 1C-2O bond length decreased and was less likely to break with increasing electric field.

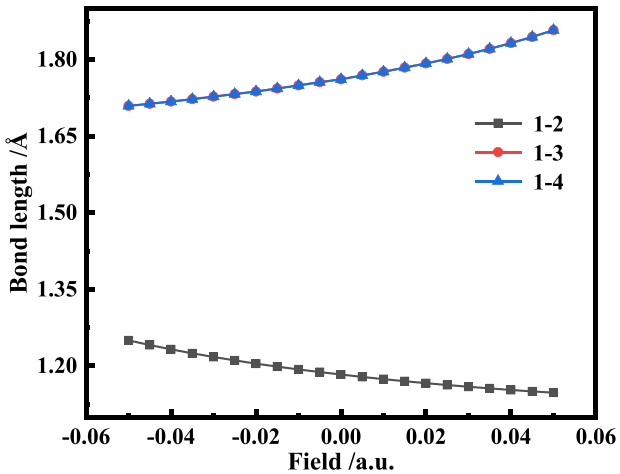

Figure 2. The bond length of phosgene molecule with external electric field

3.2.2. Total energy and dipole moment

The total energy and the dipole moment of phosgene were calculated with various external electric fields as shown in Figure 3. The total energy of the molecule initially increased and then decreased with the increase of electric field, while the dipole moment had changed oppositely. In view of the interaction between the intramolecular electric field and the external electric field, electrons in the molecule exhibited a directional shift. The negative charge moved along the opposite direction of the electric field, and the phosgene molecule was stretched. In other words, the molecule was polarized by the electric field, and the dipole moment decreased and then increased. On equation, $H_{int} = -\mu F$, the molecular dipole moment decreased initially and then increased, so the Hamiltonian increased initially and then decreased, and the total energy of the molecular increased initially and then decreased [22].

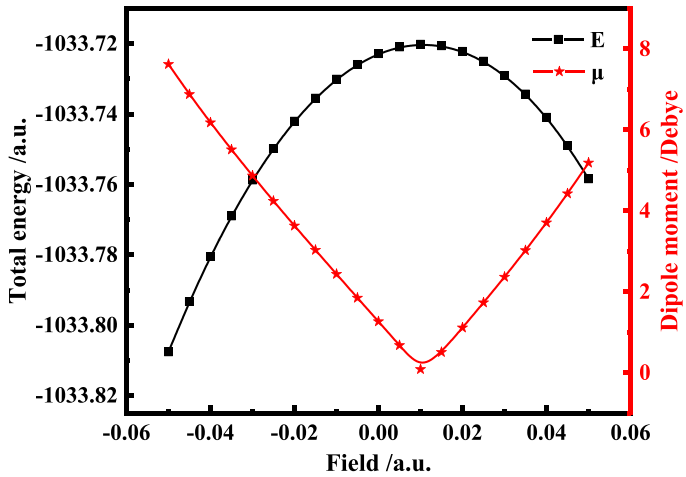

Figure 3. The total energy and the dipole moment of phosgene molecule with external electric field

3.2.3. Energy level distribution

Molecular frontier orbitals can determine many molecular properties, and thus they are important in physics and chemistry [26]. The lowest-unoccupied molecular orbital (LUMO) represents the molecular ability to obtain electrons, and lower values make it easier to obtain electrons. The highest-occupied molecular orbital (HOMO) is easily losing electrons, and higher values make it easier to lose electrons. This energy gap easily participates in chemical reactions, and smaller energy gaps make it easier to promote the molecule to the excited state and undergo chemical reactions.

The LUMO energy (E_L) and the HOMO energy (E_H) of the phosgene molecule were calculated for various external electric fields. The energy gap is given as follows:

$$E_G = (E_L - E_H) \times 27.2eV \tag{3}$$

With increasing electric field, the molecular orbital of LUMO and HOMO changed significantly as shown in **Figure 4**. The LUMO and HOMO electrons were evenly distributed without electric field. With increasing electric field, the LUMO and HOMO electrons were transferred, especially those of LUMO. As the electrons were attracted to the external field, the HOMO electrons were almost distributed onto the 3Cl and 4Cl atoms. In **Figure 5**, E_L initially increased and then decreased, while E_H decreased slowly, which increased E_G initially and then decreased with the electric field. This shows that chemical reactions can occur when excited electrons easily leave an orbit and form a hole [27], which is consistent with the above conclusion.

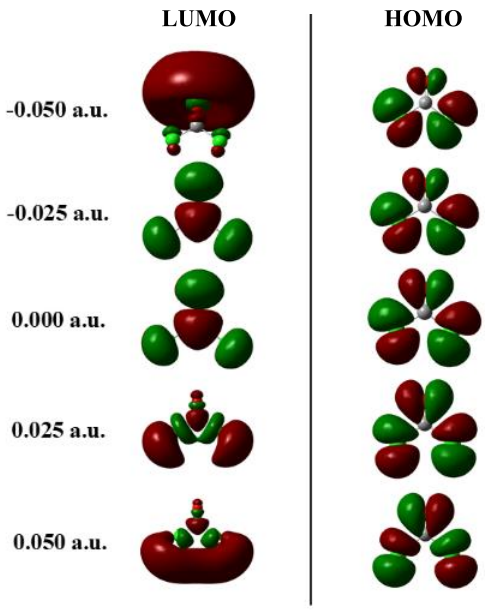

Figure 4. The frontier molecular orbital of phosgene molecule with external electric field

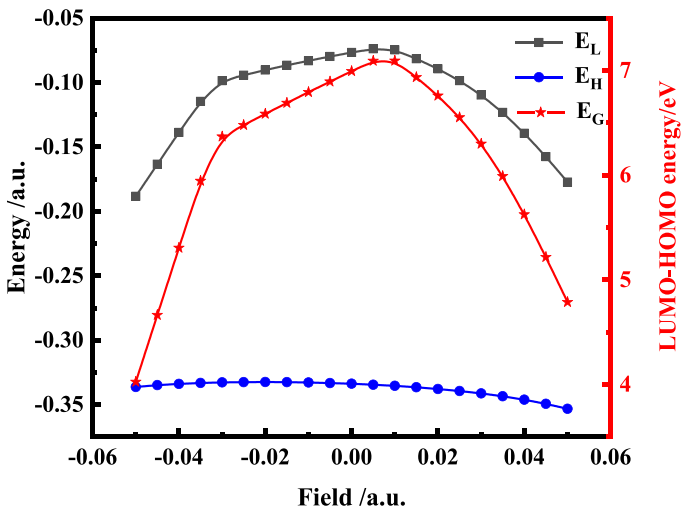

Figure 5. The energy level distribution of phosgene molecule with external electric field

3.3. Spectral characteristic of phosgene in external electric field

The spectral characteristic of a molecule is important for understanding its properties and structure. Various external electric fields (−0.05~0.05 a.u.) were applied along the direction of the arrow, and the phosgene molecular structure was optimized to calculate IR and Raman spectra. The spectral changed significantly in the electric field. The vibrational changes of the C-Cl bonds are of great significance when examining the dissociation mechanism of phosgene with external electric field. It is possible to speculate whether chemical bonds will break based on frequency changes.

Changes in the IR spectrum in the electric field are shown in **Figure 6**. The phosgene molecule has 6 vibrations. As shown in **Figure 6(a)**, the stretching vibration frequency of the 1C-2O bond (CO str) increased (blueshifted) with increasing electric field. With increasing electric field, the asynchronism stretching vibration frequency of the 1C-3Cl and 1C-4Cl bonds (CCl a-str) decreased (redshifted). The range over 250~600 cm^{-1} was expanded for a clearer visualization of the spectral shifts as shown in **Figure 6(b)**. As the electric field increased, the plane deformation vibration frequency of the C atom (C p-deform), the synchronism stretching vibration frequency of the 1C-3Cl and 1C-4Cl bonds (CCl s-str), the 1C-2O bond deformation vibration frequency (CO deform), and the deformation vibration frequency of the 1C-3Cl and 1C-4Cl bonds (CCl deform) all decreased; this means that they were redshifted.

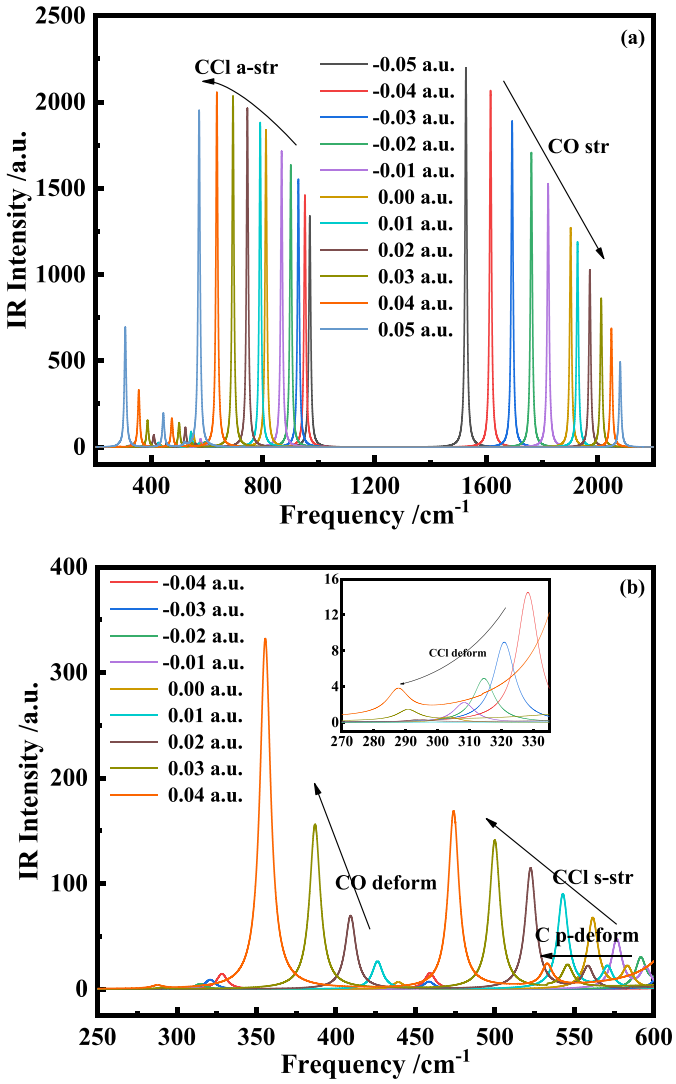

Figure 6. The IR spectrum of phosgene molecule with external electric field

3.4. Excited state of phosgene in external electric field

In order to further study the properties of phosgene, the transition selection rule $\Delta S = 0$, the wavelengths (λ), and oscillator strengths (*f*) of the first 10 singlet excited states of the molecule with external electric fields (0~0.05a.u.) were calculated using the TDDFT method B3LYP/6-31+G(D) basis set, as shown in **Table 2**. It can be seen from the data that the oscillator strengths of most transitions were equal to 0 or close to 0, thus belonging to forbidden transitions. The 1st and 5th excited states were in forbidden transitions under zero electric field and became allowed transitions when an external electric field was applied [28]. However, the second excited state was the opposite. With the increased of the external electric field, the wavelength basically increased (redshifted). Generally, the external electric field has a great influence on the properties of the excited states.

Table 2. Wavelength and oscillator intensity of singlet excited state of phosgene molecule with external electric field

State	Field/a.u.											
	0		0.01		0.02		0.03		0.04		0.05	
	λ/nm	*f*	λ/nm	*f*	λ/nm	*f*	λ/nm	*f*	λ/nm	*f*	λ/nm	*f*
n=1	232.30	0	227.14	0	236.36	0.0013	299.29	0.0071	469.34	0.0148	968.56	0.0297
n=2	202.38	0.0026	210.63	0.0080	231.31	0	277.14	0	423.26	0	867.27	0
n=3	200.39	0	194.73	0.0000	220.28	0	239.90	0.0001	290.30	0.1725	385.97	0.2074
n=4	186.87	0.0004	187.26	0.0288	206.14	0	226.03	0.1495	264.91	0.0017	314.89	0.0048
n=5	180.34	0	186.01	0	198.76	0.0360	224.18	0.0205	252.87	0.0004	296.34	0.0002
n=6	177.66	0	184.71	0	188.25	0.0408	211.95	0	250.33	0	290.57	0..0094
n=7	177.43	0	171.66	0.0091	184.91	0.1983	205.53	0	236.34	0.0121	282.40	0.0471
n=8	172.32	0.0513	171.16	0	180.96	0.0033	203.49	0.0503	232.59	0.0332	265.14	0.0016
n=9	164.68	0.0083	167.82	0.0297	175.49	0.0422	199.37	0.0112	217.65	0.0003	259.74	0.0065
n=10	161.82	0.4332	165.51	0.3574	175.40	0.0002	195.30	0.0573	213.64	0.0706	245.26	0

4. Conclusion

The ground-state geometric structure, the spectral characteristic, and singlet excited state of phosgene in various external electric fields (−0.05~0.05 a.u.) were calculated via DFT or TDDFT with the B3LYP/6–31+G(d) basis set. The effect of electric field on the bond length, total energy, dipole moment, energy-level orbital distribution, LUMO-HOMO energy gap, IR spectra, as well as the wavelength and oscillator intensity of the singlet excited state was analyzed. The phosgene structure changed significantly in the electric field. With increasing electric field, the 1C-2O bond length decreased, while the 1C-3Cl and 1C-4Cl bond lengths increased. In the electric field, the total energy of the molecule first increased and then decreased, while the dipole moment changes were opposite; the LUMO-HOMO gap first increased and then decreased. With increasing electric field, most of the IR vibrational frequencies were redshifted. The wavelength of the singlet excited state increased, reflecting a redshift. The oscillator strengths of most transitions were equal to 0 or close to 0, thus belonging to forbidden transitions. The calculated ground-state geometric data, spectral characteristic, and the singlet excited state of phosgene indicate that it can be decomposed by external electric field. This will provide theoretical guidance for investigations of the dissociation of phosgene.

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The authors declare no conflict of interest.

References

[1] Molina MJ, Rowland FS, 1974, Stratospheric Sink for Chlorofluoromethanes: Chlorine Atomc-Atalysed Destruction of Ozone. Nature, 249(5460): 810-812.

[2] Zhang ZM, 1999, Who Discovered the Ozone Hole?. Friends of Chemical Industry, 39(02): 45.

[3] Chen HY, Lien CY, Lin WY, 2009, UV absorption Cross Sections of Cloocl Are Consistent with Ozone Degradation Models. Science, 324(5928): 781.

[4] Lan YC, Wang H, Wu LX, et al., 2012, Electroreduction of Dibromobenzenes on Silver Electrode in the Presence of CO_2. Journal of Electroanalytical Chemistry, 664(15): 33-38.

[5] Wu HY, 2006, Analysis of Halon Substitute Agent Environment Affection and Study on Extinguishing System of Halon Substitutes, Tianjin University, Tianjin.

[6] Li XH, Liu YZ, Chen YY, et al., 2018, Investigation on Molecular Properties of Freon 13 in External Electric Field. Journal of Molecular Science, 34(2): 139-143.

[7] Xu HP, Ying YH, 2016, The molecular Structure and Properties of Agcl Under External Electric Field. Journal of Atomic and Molecular Physics, 33(1): 1-7.

[8] Zhou ZY, Liu YZ, Li J, et al., 2017, Influence of External Electric Field on the Molecular Structure and Electronic Spectrum of Formaldehyde Molecule. Journal of Molecular Science, 33(3): 217-224.

[9] Wang JP, Zhai DD, Ma P, et al., 2020, Theoretical Insight into the Effects of External Electric Field on Cocrystal HMX/DMI. Journal of Propellants and Explosives, 43(2): 133-138.

[10] Vossnacke P, Wust A, Keilhack T, et al., 2021, Novel Synthetic Pathway for the Production of Phosgene. Science Advances, 7(40): 5186.

[11] Li J, Liu YZ, Yin WY, et al., 2017, Spectra and Dissociation Properties of Freon 31 Under Electric Field. Spectroscopy Letters, 50(10): 572-578.

[12] Hobson ST, Casillas RP, Richieri RA, et al., 2019, Development of an Acute, Short-Term Exposure Model for Phosgene. Toxicology Mechanisms and Methods, 29(8): 604-615.

[13] Olivera DS, Hoard-Fruchey H, Sciuto AM, 2016, Evaluation of an in Vitro Screening Model to Assess Phosgene Inhalation Injury. Toxicology Methods, 27(1): 45-51.

[14] Hobson ST, Richieri RA, Parseghian MH, 2021, Phosgene: Toxicology, Animal Models, and Medical Countermeasures. Toxicology Mechanisms and Methods, 31(4): 293-307.

[15] Lu QY, Huang SY, Meng XY, et al., 2021, Mechanism of Phosgene-Induced Acute Lung Injury and Treatment Strategy. International Journal of Molecular Sciences, 22(20): 10933.

[16] Pitschmann V, Matejovsky L, Zeman J, et al., 2020, Second-Generation Phosgene and Diphosgene Detection Tube. Chemosensors, 8(4): 107.

[17] Khan S, Sajid H, Ayub K, et al., 2020, High Sensitivity of Graphdiyne Nanoflake toward Detection of Phosgene, Thiophosgene and Phosogenoxime; A First-Principles Study. Journal of Molecular Graphics and Modelling, 100(prepublish): 107658.

[18] Wang SL, Zhong L, Song QH, 2018, Sensitive and Selective Detection of Phosgene, Diphosgene, and Triphosgene by a 3,4-Diaminonaphthalimide in Solutions and the Gas Phase. Chemistry (Weinheim an der Bergstrasse, Germany), 24(21): 5652-5658.

[19] Carlos LHJ, Baptiste S, Laurent V, et al., 2018, Thermal Decomposition of Phosgene and Diphosgene. The Journal of Physical Chemistry A, 122(1): 249-257.

[20] Liu YZ, Li XH, Wang JF, et al., 2017, Study on Dissociation Properties and Spectra of Halon 1301 in External Electric Field. Spectroscopy and Spectral Analysis, 37(03): 679-684.

[21] Zhang XYZ, Liu YZ, Ma XY, 2018, Dissociation and Physical Properties of Methyl Iodide in External Electric Field. Journal of University of Chinese Academy of Sciences, 35(06): 839-844.

[22] Wu YG, Liu JX, Liu HL, et al., 2019, Spectrum and Dissociation Properties of Fluoro Trichloro Methane Molecule in Radiational Field. Acta Physical Sonica, 68(06): 64-72.

[23] Frish MJ, Trucks GW, Schlegel HB, et al., 2010, Gaussian 09, Revision C. 01., Gaussian, Inc., Wallingford.

[24] Shimanouchi T, 1977, Tables of Molecular Vibrational Frequencies. Consolidated. Volume II. Journal of Physical and Chemical Reference Data, 6(3): 103.

[25] Zhu ZH, 1991, Atomic and Molecular Reaction Statics, Science Press, Beijing.

[26] Cardona CM, Li W, Kaifer AE, et al., 2011, Electrochemical Considerations for determining Absolute Frontier Orbital Energy Levels of Conjugated Polymers for Solar Cell Applications. Advanced Materials, 23(20): 2367-2371.

[27] Li J, Liu YZ, Cheng QY, et al., 2017, Study on the Physical Characteristics of Halon-1211 Under the Electrical Fields. Journal of Atomic and Molecular Physics, 34(6): 1017-1024.

[28] Yin YH, Wang L, 2017, Structure and Properties of AgBr Molecule Under External Electric Field. Journal of Atomic and Molecular Physics, 34(1): 9-15.

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UAV Path Planning Based on an Improved Ant Colony Algorithm

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Abstract: Reviews and experimental verification have found that existing solution methods can be used to solve UAV path planning problems, but each approximate solution has its own advantages and disadvantages. For example, ant colony algorithm easily falls into the local optimum in the process of realizing path planning. In order to prevent too low pheromones on the longer path and too high pheromones in the shorter path, the upper and lower limits of pheromones as well as their volatile factors are set to avoid falling into the local optimum. Secondly, multi-heuristic factors are introduced, and the overall length of the path serves as an adaptive heuristic function factor that determines the probability of state transition, which affects the probability of ants choosing the corresponding path. The experimental results show that the path length planned by the improved algorithm is 93.6% of the original algorithm, and the optimal path length variance is only 14.22% of the original algorithm. The improved ant colony algorithm shortens the optimal path length and solves the UAV path planning problem in terms of local optima. At the same time, multiple enlightening factors are introduced to increase the suitability of UAV for complex environments and improve the performance of UAV.

Keywords: UAV; Path planning; Ant colony algorithm

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1. Introduction

With the advancement of modern science and technology, the tasks that UAV can perform are continually increasing [1]. For example, UAV can undertake the task of transporting emergency materials, such as medical rescue kits. In order to better apply UAV to practice, scholars have done a lot of research on UAV path planning and have proposed numerous algorithms to increase the efficiency of path planning. The algorithms include artificial potential field method [2], A* algorithm [3], ant colony algorithm [4], genetic algorithm [5], particle swarm algorithm [6], bat algorithm [7], simulated annealing algorithm [8], fast expanding random tree algorithm [9], D* algorithm [10], artificial fish swarm algorithm [11], locust algorithm [12], firefly algorithm, and so on [13]. Genetic algorithm uses codes to represent the solution of the problem. Following the operation of the codes such as selection, crossover, mutation, and so on, the fitness and function values are used as the evolutionary assessment basis, and finally the optimal population, that is the solution to the problems [14], is obtained. Ant colony algorithm and genetic algorithm operate similarly when selecting the optimal solution. The ant colony algorithm seeks the optimal solution through iteration, but it has no crossover and mutation operations when searching for the optimal solution; therefore, the solution is simpler.

Ant colony algorithm is a heuristic search algorithm, which was proposed by DRIGO in the early 1990s by simulating the foraging behavior of ants in the environment [15]. The characteristics of ant colony algorithm include positive feedback, parallel computing, good robustness, and so on [16]. Many scholars have applied the ant colony algorithm to path planning and have achieved successful results. The ant colony algorithm can be used to solve discrete optimization problems since it has a wide search range and a fast convergence speed [17]. However, due to the positive feedback characteristics of the algorithm, pheromones may accumulate on local paths, thus leading to problems, such as falling into the local optimum [18,19]. The ant colony algorithm takes the distance between the current position and the next position as heuristic information. When faced with obstacles, there are still several problems in avoiding them in advance [16]. Hence, many scholars have been working to improve the flaws in the algorithm. With the deepening of research and the characteristics of path planning, the focus is on how to improve the search efficiency of the algorithm [20].

Path smoothing can reduce the flight risk of UAV. Huang and other researchers have introduced the degree smoothing method to generate a smooth path [21]. As the distance between the current node and several neighboring nodes is equal, inspiration cannot play a role in the selection of the next node, so it has been proposed that the shortest distance between the starting point and the target point should be taken as the guide for path search [22]; by calculating the reciprocal of the weighted sum of the distance between the current node and the next node to be left as well as the vertical distance from the next node to the shortest path, the search of the algorithm can be accelerated. Sun Gongwu and others have designed an adaptive heuristic function that takes into account the distance between the current grid and the grid to be walked as well as the distance between the grid to be walked and the target grid to select better nodes, but the adaptive heuristic function only considers the current grid as well as the distance between the grid to be walked and the target grid [23]. Based on the concept of multi-scale path search, Huang Xin and others have proposed an improved guidance factor, which takes into account the distance from the node to the target point and the distance from the node to the starting point; in addition, the flight of the UAV is determined by the height of the terrain but only partially considers the guidance function of the heuristic function [24]. In regard to path smoothing, Li Li and others have introduced the number of turns into the heuristic function, which influenced the improved heuristic function; they also improved the pheromone updating mechanism and the path smoothness, providing good convergence and global searching ability; however, the transition probability is only affected by pheromone and heuristic function, and the iteration times are large, which makes it easy to fall into the local optimum [25].

Huang and other researchers introduced the K-degree smoothing method to the path smoothing problem [21], while Li Li and other researchers did not only consider the smoothing problem in the heuristic function, but also the number of turns of the path in the heuristic function [25]. Tao and others improved the transition probability to enhance the convergence speed of the algorithm, thus improving the performance of the algorithm; however, the obtained path length is not the shortest [22]. An adaptive heuristic function has been designed in a study [23] according to the distance between the current grid and the target grid, but it only considered the path length, whereas the heuristic function of in the study conducted by Li Li [25] considered many heuristic factors. In another study [24], the leading factor of nodes was introduced into the transition probability; however, it did not improve the inspiring factor. Li Li and other researchers considered the number of turns and the smoothness of the path while making the path as short as possible, and they proposed a multi-heuristic ant colony algorithm that takes the distance correction function, safety function, and smoothness function into account [25]. When ants look for the best path, the path is chosen based on multiple heuristic factors.

In a study [25], the path factor only considers the distance from each adjacent grid of the current grid to the target grid but does not consider the integrity of the path. In this study, under the influence of multiple

heuristic factors and considering the integrity of the path, the guiding factor mentioned in the study [24] conducted by Huang Xin is introduced into the transition probability, and the heuristic function, pheromone, and pheromone volatilization factor are processed to increase the accuracy of the algorithm. The results reveal that this method improves the efficiency of path search, reduces the number of iterations, and optimizes the path length.

2. Environmental modeling

In this study, a two-dimensional grid method [26] is used to model the path environment. Taking into account the safety of drones, the distance between the drone's path and the grid obstacles is set to be half of the grid length. Each grid has eight adjacent grids [27] that can be walked, as shown in **Figure 1**. $dis(i,j)$ represents the distance from the current grid i to its j-th adjacent grid.

$$dis(i,j) = \begin{cases} 1, & When\ ants\ go\ 2,4,6,8, \\ \sqrt{2}, & \text{When ants go } 1,3,5,7. \end{cases} \tag{1}$$

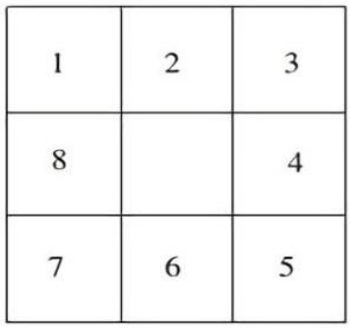

Figure 1. Eight adjacent grids, with the middle grid as the current grid

The process of ants selecting the next grid is discussed below.

(1) **Step 1**: Determine whether there is an obstacle in grid 1. If there is an obstacle, as shown in **Figure 2**, then $dis(i,j) = \infty$; otherwise, proceed to **Step 2**.

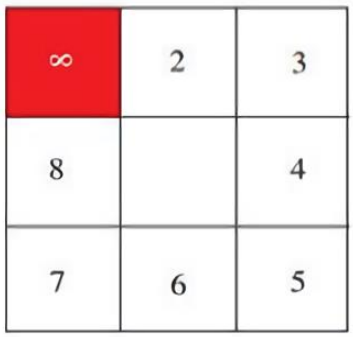

Figure 2. Grid 1 is an obstacle and the distance from the current grid to grid 1 is infinite in this situation

(2) **Step 2:** Determine whether the adjacent grid 1 is out of bounds; that is, beyond the range of the terrain. If it is out of bounds, as shown in **Figure 3**, grids 1, 2, 3, 7, and 8 are out of bounds; otherwise, $dis(i,j) = \infty$, proceed to **Step 3**.

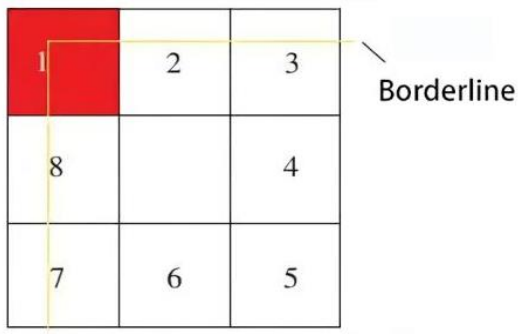

Figure 3. Part of the grids on the boundary

(3) **Step 3:** Determine whether the adjacent grid 1 is a grid in an even direction or in an odd direction. If it is in an even direction, $dis(i,j) = 1$; otherwise, proceed to **Step 4**.
(4) **Step 4:** Determine whether one or both of the two even-numbered grids adjacent to the odd-numbered direction grid are obstacle grids. If yes, $dis(i,j) = \infty$; otherwise, $dis(i,j) = \sqrt{2}$.

3. Multiple heuristics

According to Li Li and others [25], based on the path planning requiring a short path length, only a few turns, a smooth path, and the adaptability to the environment, three factors should be considered: distance correction function, safety function, and smoothness function. The distance correction function increases the distance difference between the adjacent grids of the current grid and the target grid. When selecting the next grid to be walked on, increasing the path length is an inspiration to the ants. The safety function has a certain guiding effect on the turning of the UAV in flight. When the current direction of the UAV is the same as that of the previous moment, the safety function value of this direction will be larger. The smoothness function will inspire the drone to choose a gentle path.

3.1. Distance correction function

$$\varphi(i,j) = \frac{\text{dis }(i)_{max} - \text{dis}(i,j))}{\text{dis }(i)_{max} - \text{dis }(i)_{min} + 0.001} \times \gamma_1 \times g_1 \tag{2}$$

$\text{dis}(i)_{max}$ is the maximum distance between the adjacent grids of the i-th grid and the center of the target grid; $\text{dis}(i)_{min}$ is the adjacent grids of the i-th grid the minimum distance between the center of the grid and the target grid; $\varphi(i,j)$ is the corrected distance between the center of the j-th grid and the center of the target grid in the adjacent grids of the i-th grid; γ and g are the correction parameters.

3.2. Safety function

If the projected course rotates more during the flight, it will not only increase the distance of the flight path, but also the degree of hazard. Therefore, it is necessary to reduce the number of turns as much as possible in path planning.

$$r_{ij}(t) = \begin{cases} \dfrac{u}{J(\text{allowed}_i)}, i = \text{visited}_i, \\ \theta u, dr_{zi}(t) = dr_{ij}(t), \\ \dfrac{(1-\theta)u}{J(\text{allowed}_i)}, dr_{vi}(t) \neq dr_{ij}(t) \end{cases} \tag{3}$$

In the formula, $J(\text{allowed}_i)$; $r_{ij}(t)$ is the safety function; u is the heuristic constant; θ represents the importance of safety; visited_i is the t-th iteration, the k-th ant goes to the current set of grid numbers that have been passed in grid i; v is the label of the previous grid of the current i-th grid, $v = \text{visited}_i(\text{end} - 1)$; $\text{J}(\text{allowed}_i)$ represents the number of feasible adjacent grids of the current grid; $dr_{vj}(t)$ represents the direction from the v-th to the i-th grid at the t-th iteration; $dr_{ij}(t)$ represents the t-th iteration, the direction from the i-th grid to the j-th grid is turned. By comparing $dr_{vj}(t)$ and $dr_{ij}(t)$, if the two are the same, it will increase the possibility of continuing in the same direction in the following step, allowing the path to retain a straight line.

3.3. Smoothness function

$$h(i,j) = \frac{h_{max} - |h(i) - h(j)|}{h_{max} - h_{min} + 0.001} \times \gamma_2 + g_2 \tag{4}$$

h_{max} is the maximum value of the difference between the height of the current i-th grid and the height of its adjacent grid; h_{min} is the minimum value of the difference between the height of the current i-th grid and the height of its adjacent grid; $h(i)$Is the height of the grid.

4. Improved ant colony algorithm

The ant colony is required to select the next grid from the eight adjacent grids based on pheromone, heuristic function, and transition probability as well as to determine the nearest path from the starting point to the destination point. Before the ant colony begins to find a path, the pheromone of each grid is the same. The ant selects the next grid to walk according to the transition probability. The pheromone of the path will be left, and the pheromone of the path that has not been walked will be continuously reduced in the iteration. Ants on the shorter path locate food quickly, while ants on the longer path take a longer time to locate food. Therefore, the sum of pheromones left by ants on the shorter path is more, thus attracting more ants to take this path. The shortest path can then be found.

4.1. Transition probability

The transition probability of the ant colony algorithm is affected by two factors: the heuristic function and the pheromone left by ants. There are obstacles in the real environment. The multi-heuristic function enables ants to avoid obstacles, choosing a shorter path and reducing the number of turns. The path with more pheromones will attract ants to choose the path. When a large number of ants walk from the same path and fail to find the optimal path, the current path is considered as the global optimum; in that case, the ants fall into the local optimum.

4.1.1. Adaptive heuristic function factor

In order to improve the search efficiency of an optimal path and jump out of the local optimum, an adaptive heuristic function factor is introduced into the transition probability, as shown in equation (5). The adaptive heuristic function factor is the weighted reciprocal of the sum of the distance from the current grid to the starting grid as well as the distance from the current grid to the destination grid. Based on the distance between the grid to be walked and the target grid, add the distance from the grid to the starting grid; that is, when considering whether the grid to be walked is the best, the adaptive heuristic function factor is taken as one of the influencing factors of the transition probability to increase the overall consideration of the environment.

$$\mu_{ij} = \frac{1}{a(d_{jE})} + \frac{1}{b(d_{Aj} + d_{jE})} \tag{5}$$

μ_{ij} is the adaptive heuristic function factor; d_{Aj} represents the distance between the starting point and the grid to walk in; A is the starting point; j is the label of the grid to walk in; d_{jE} is the distance between the grid to walk in and the destination point; E is the destination point; a and b are the weight coefficients. The smaller the distance between the grid to walk in and the starting point as well as that between the grid to walk in and the destination point, the larger the adaptive heuristic function factor and the transition probability. In that case, a shorter path can be better selected.

By drawing an adaptive heuristic function factor into the transition probability, the ants can select the shortest path and speed up the efficiency of searching the optimal path.

4.1.2. Improved transition probability

The transition probability has been improved as follows:

$$P_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau_{ij}(t)]^{\alpha}[\eta_{ij}(t)]^{\beta}\mu_{ij}}{\sum_{s\in \text{ allowed}k}\ [\tau_{is}(t)]^{\alpha}[\eta_{is}(t)]^{\beta}\mu_{is}}, j \in \text{ allowed }_{k}, \\ 0, j \notin \text{ allowed }_{k}, \end{cases} \tag{6}$$

k is the label of ants; i is the current grid number; j is the following grid number; t is the current number of iterations; τ represents the pheromone strength; η represents the heuristic function; α represents the degree factor of pheromone; $\beta$is the heuristic factor; allowed_k is the grid that can be selected next. The ants at the back will be guided according to the pheromones left by the ants in front. The shorter the path is, the more pheromones will be left, but pheromones will evaporate at the same time. The updated pheromone is determined as follows:

$$S_k(t) = XL_k(t) + YF_k(t) + ZT_k(t) \tag{7}$$

$$\Delta\tau_{ij}(t) = \begin{cases} \dfrac{Q}{S_k(t)}, i, j \in \text{ visited }_{tq} \\ 0, \text{ othervise}, \end{cases} \tag{8}$$

$$\tau_{ij}(t+1) = (1-\rho)\tau_{ij}(t) + \sum_{k=1}^{M} \Delta\tau_{ij}(t) \tag{9}$$

$S_k(t)$ is the path comprehensive indicator in the *t*-th iterative of the *k*-th ant; the smaller the $S_k(t)$ is, the better the route; $L_k(t)$ is the path length; $F_k(t)$ is the mean square deviation of the grid height the ant has walked in; $T_k(t)$ is the number of turns of the path when the ant is walking; X, Y, and Z are the adjustment coefficients of the above three factors; M is the total number of ants; ρ represents the pheromone volatilization factor; Q represents the pheromone constant; visited_{tq} is an ordered collection of grid labels passed of the *k*-th ant from the *t*-th iteration to the *q*-th grid.

In this study, the initial pheromone adopts a fixed value and sets the range of pheromone to prevent ants from falling into the local optimum when searching for the optimal path.

$$\tau_{ij}(t) \geqslant \tau_{ij}(t)_{min} \tag{10}$$

$$\tau_{ij}(t) < \tau_{ij}(t)_{max} \tag{11}$$

At the same time, a bounded setting is formed for the pheromone volatilization factor, $i\sigma\rho > \rho_{min}$, then $\sigma\rho > \rho$; otherwise, $\rho = \rho_{min}$.

4.2. Heuristic function

The Euclidean distance from the current grid to its adjacent grid is added to the heuristic function as one of the factors affecting the heuristic function. Through the distance correction function, an adjacent grid closest to the target grid is selected from the adjacent grids of the current grid. The distance from the current grid to its adjacent grid is not exactly the same. In order to more accurately consider the influence of the path length on the ant colony's selection of the following grid, the Euclidean distance $d(i,j)$ from the current grid to its adjacent grid is added to the heuristic function. When the distance $d(i,j)$ increases, the value $\frac{1}{d(i,j)}$ will decrease, making multiple heuristic function values $\eta_{ij}(t)$ decrease; the value of the transition probability is then influenced to form a closed-loop feedback. The heuristic function is shown in equation (12).

$$\eta_{ij}(t) = \frac{1}{d(i,j)} + \varphi(i,j) + h(i,j) + r(i,j) \tag{12}$$

$d(i,j)$ is the Euclidean distance between the *i*-th grid center and the *j*-th grid center; $\varphi(i,j)$ is distance correction function; $r(i,j)$ is a security function; $h(i,j)$ is the smoothness function.

5. Algorithm simulation

5.1. Algorithm flow

(1) **Step 1:** Build the grid map and set the coordinates of the starting point A and destination point E.
(2) **Step 2:** Initialize parameters, place all the ants on the starting point, and build a tabu table.
(3) **Step 3:** Calculate the heuristic function and transition probability according to equations (12) and (6), respectively, to determine the next grid that the ant will walk in; fill in the number of the grid that has been passed by the ant in the tabu table; when the ant reaches the destination, it completes a search and records the optimal path of this iteration.
(4) **Step 4:** Update the pheromone according to equation (9).
(5) **Step 5:** Compare the optimal path of each iteration to determine the current optimal path.
(6) **Step 6:** Judge whether the number of iterations reaches the maximum; if it reaches the maximum, output the result; otherwise, continue the iteration.

According to the above steps, the pseudocode of the improved ant colony algorithm is given as follows:

Algorithm: Improved Ant Colony

```
Tabu = [ ]
Tabu ← Start grid numter;
while t ≤ t_max
for each ant do
  η_ij(t) ← each ant;
  P_ij^κ(t) ← each ant;
  j ← η_ij(t) , P_ij^κ(t) ;
  Tabu ← j ;
stpath ← path ;
update τ ;
  end
bestpath ← ChooseBestPath(stpath) ;
end
```

The algorithm flow chart is shown in **Figure 4**.

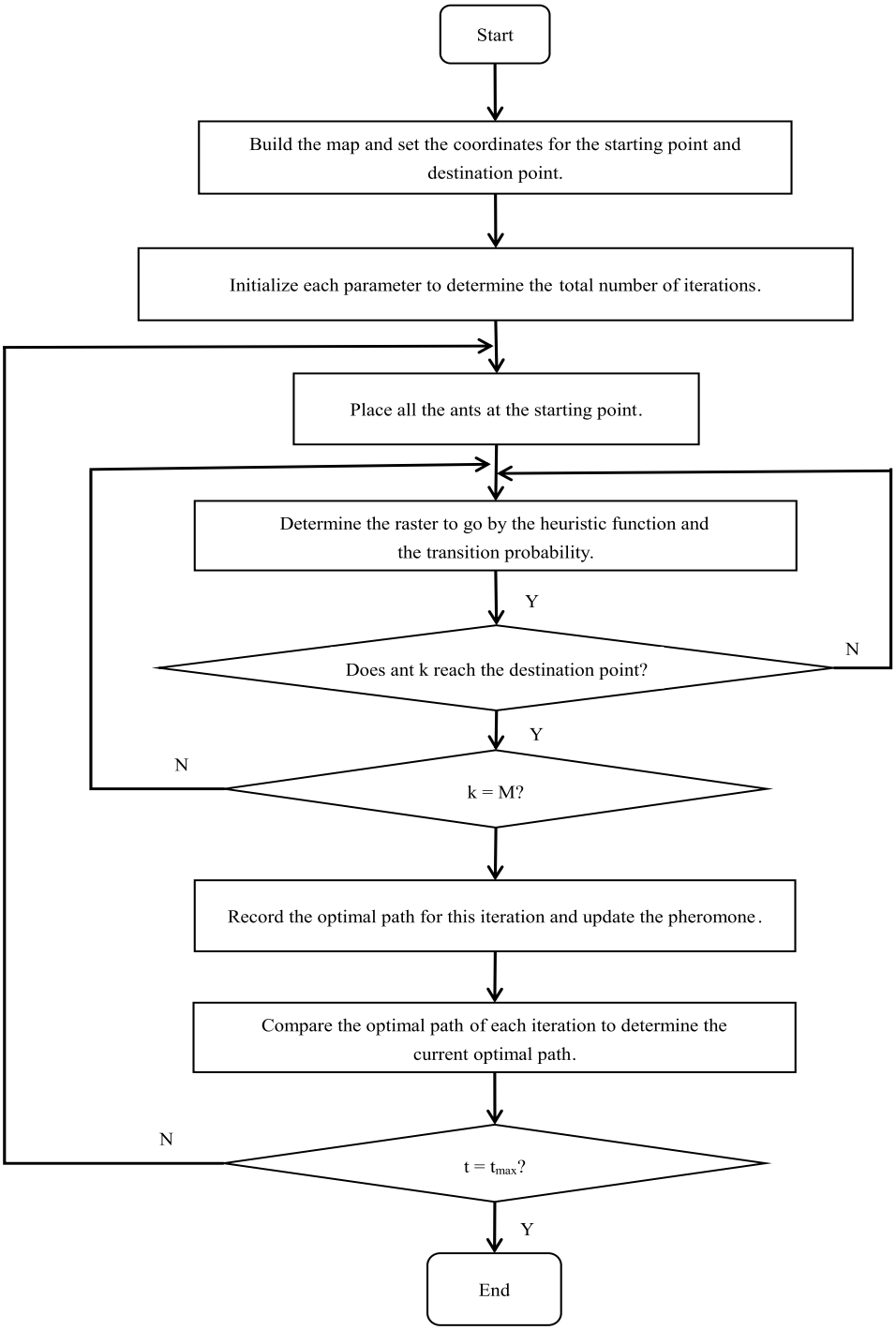

Figure 4. A flow chart of the improved ant colony algorithm

5.2. Parameter setting

In order to better compare the data, the parameters in this study are changed based on the parameters used in the comparison algorithm. Continue to run and debug according to experience to find the appropriate value. **Table 1** shows the initialization parameters.

Table 1. Initialization parameters

Algorithm	l_{max}	M	p	Q	γ_1	g_1	γ_2	g_2	u	θ
Literature [25]	30	50	0.3	100	10	1	10	1	10	0.5
Improved algorithm in this study	30	50	0.3	100	10	1	10	1	10	0.5

Algorithm	$\tau_{ij}(t)_{min}$	$\tau_{ij}(t)_{max}$	ρ_{min}	$\tau_{ij}(o)$	X	Y	Z
Literature [25]	10	40	0.2	20	1	0.1	0.1
Improved algorithm in this study	10	40	0.2	20	1	0.1	0.1

5.3. Simulation comparison

In order to improve the reliability of the transition probability, this study improves the transition probability, introduces the adaptive heuristic function factor, and takes the Euclidean distance from the current grid to its adjacent grid as one of the influencing factors of the heuristic function. As the technique employed in this study is a heuristic random optimization method, this study employs MATLAB to simulate and compare the improved algorithm to a literature [25] – Path Planning Based on Improved Ant Colony Algorithm with Multiple Inspired Factor – for 30 times, in order to evaluate its efficiency. The terrain environment is studied in the 10 × 10 and the 30 × 30 grid obstacle maps.

5.3.1. Simulation in the 10 × 10 grid environment

As shown in **Figure 5**, the dotted line represents the optimal path in the aforementioned literature [25], and the solid line is the optimal path of the improved ant colony algorithm in this study. It can be seen from the figure that most of the paths overlap. However, from the overall effect of the path, the solid line has four turns, while the dotted line has six turns. When the dotted line turns for the fourth time, the solid line continues to move forward in the direction of the original path, which is smooth.

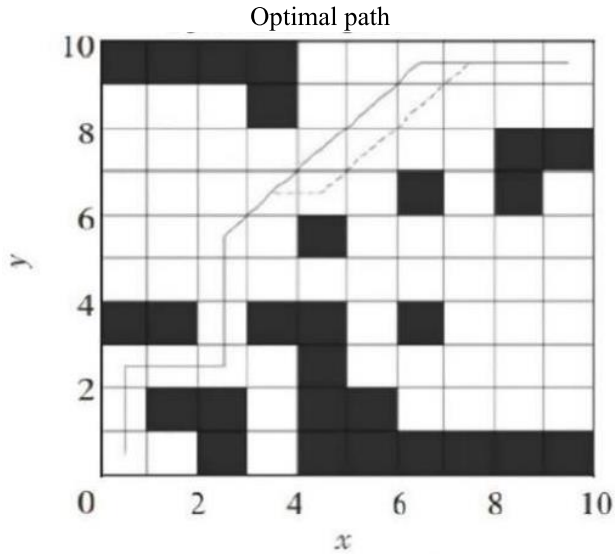

Figure 5. Graph of optimal path comparison in the 10 × 10 grid environment

Figure 6 shows the comparison of the optimal path length at different iterations. Initially, the solid line has a longer path length than the dotted line, but after iteration, the solid line finds a shorter path, whereas the dotted line does not even under the same number of iterations.

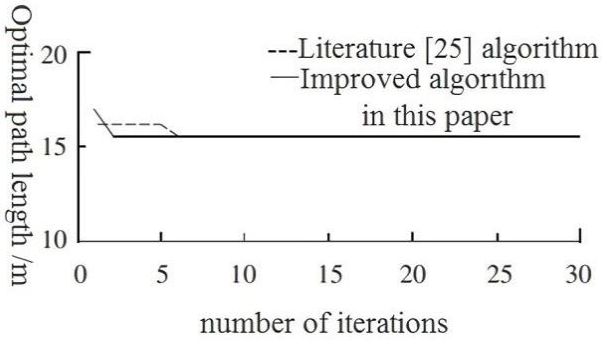

Figure 6. Graph of optimal path length in the 10 × 10 grid environment

Figure 7 compares the mean square error of the optimal path with different iterations. The initial value of the solid line is the same as that of the dotted line. With the increasing number of iterations, it can be seen that the height mean square deviation of the solid line reaches a stable value within five iterations, whereas the dotted line only reaches a stable value with more than five iterations.

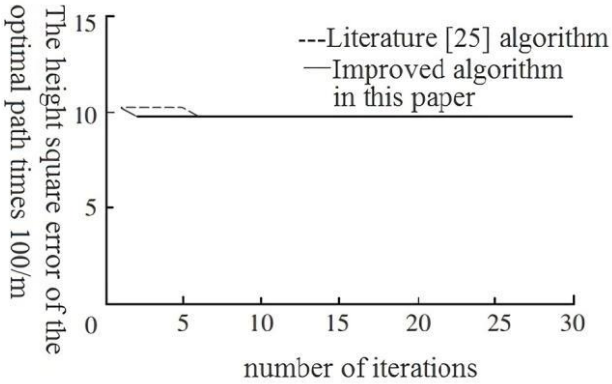

Figure 7. Comparing the mean square deviation of the optimal path height in the 10 × 10 grid environment

Figure 8 is a comparison of the number of turns of the optimal path at different iterations. It can be seen from **Figure 8** that the number of turns of the solid line and the dotted line is the same under the same number of iterations. With the increasing number of iterations, the solid line with the adaptive heuristic function factor is introduced to obtain lesser number of turns, whereas the dotted line maintains the original number of turns, which shows that the improved ant colony algorithm increases the ant colony's overall consideration of the path environment and jumps out of the local optimum.

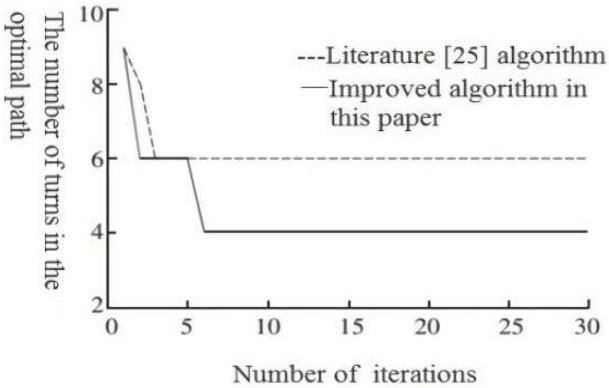

Figure 8. Comparison of number of turns of the optimal path in the 10 × 10 grid environment

Figure 9 shows a comparison of the comprehensive index and average comprehensive index of the optimal path at different iteration times. The comprehensive index is the comprehensive evaluation of the distance correction function, safety function, and smoothness function. The lower the index, the better the algorithm. As can be seen from **Figure 9**, the comprehensive index of the optimal path of the improved algorithm has a large value initially and converges to a stable value with increasing number of iterations.

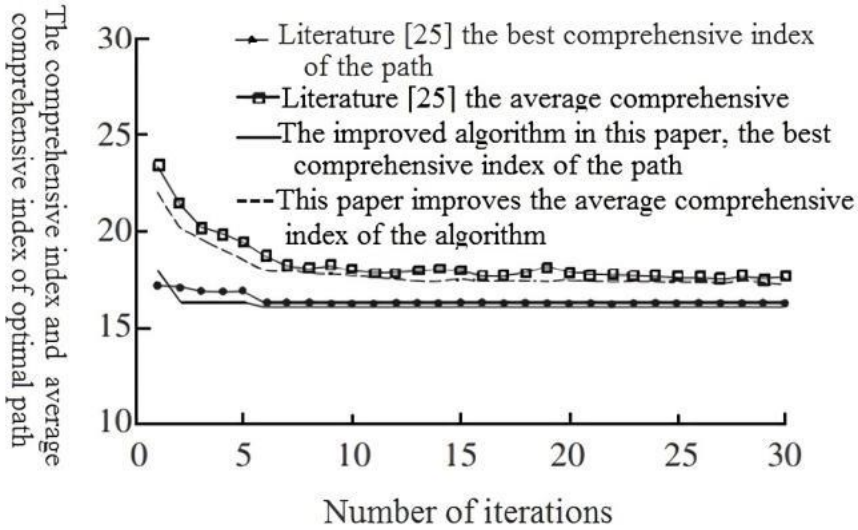

Figure 9. Comparison of the comprehensive indicators of the optimal path in the 10 × 10 grid environment

It can be seen from **Table 2** that the improved algorithm reduces the number of iterations, and the comprehensive index is relatively small. In order to reduce the influence of the randomness of the algorithm on the experimental results, the average value and variance of the optimal solution are calculated under the condition of running 30 times, as shown in the average value and variance of the optimal path length in **Table 2**.

Table 2. Simulation results of the 10 × 10 grid environment

Optimal path index	Literature [25] algorithm	Improved algorithm in this study
Path length / m	15.6	15.6
Height means square error / m	9.815	9.815
Number of turns	6	4
Comprehensive index	16.21	16.01
Number of iterations of path length	6	2
Optimal path length average	15.7000	15.6467
Optimal path length variance	0.050000	0.063156

5.3.2. Simulation in the 30 × 30 grid environment

As shown in **Figure 10**, the dotted line represents the optimal path in the aforementioned literature [25], whereas the solid line represents the optimal path of the improved algorithm in this study. From **Figure 10**, it can be seen that in the second corner, the path of the dotted line is straight, while that of the solid line is diagonal; in addition, the length of the solid line is shorter compared to the dotted line. From the overall effect of the path, the solid line has 19 turns, whereas the dotted line has 16. Considering the integrity of the path, although the number of turns increases, the length of the path decreases.

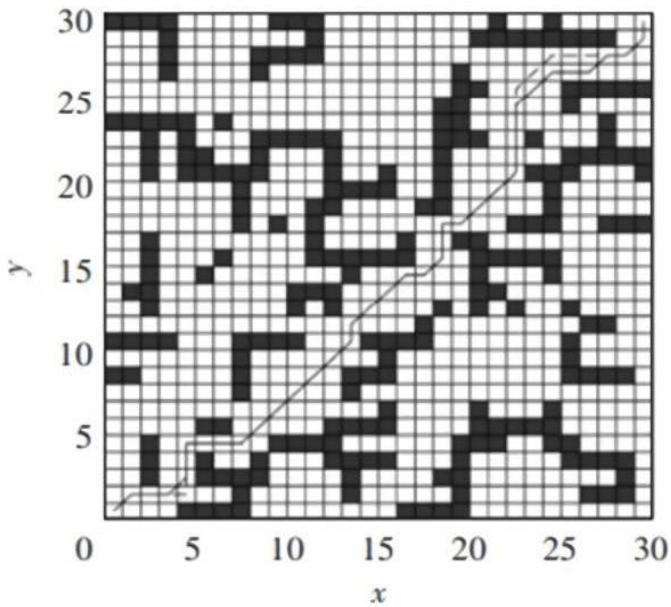

Figure 10. Graph of optimal path comparison in the 30 × 30 grid environment

Figure 11 shows the comparison of the optimal path length at different iterations. As can be seen from the figure, when the adaptive heuristic function factor is introduced, the path length of the improved algorithm is short at the beginning of the iteration. After the iteration, the shorter path is found and reaches a stable value. It can be concluded from the results that this algorithm increases the ability of ants to consider the integrity of the path and improves the efficiency of ants in searching for the optimal path.

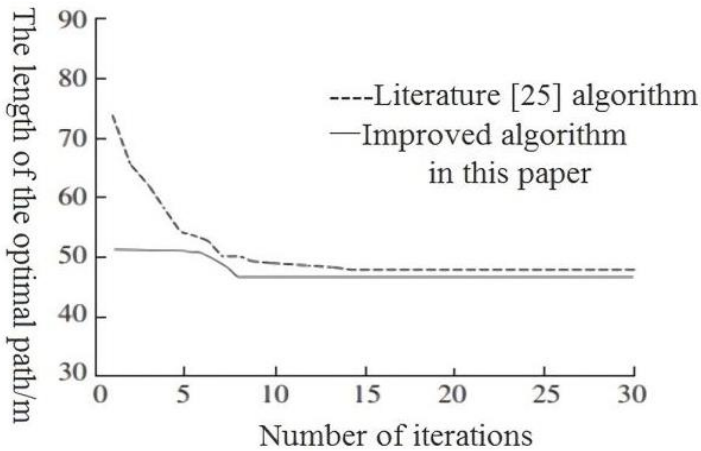

Figure 11. Comparison of optimal path length in the 30 × 30 grid environment

Figure 12 is a comparison of the height mean square deviation of the optimal path at different iterations. The initial value of the solid line is the same as that of the dotted line. With the increasing number of iterations, it can be seen that the height mean square deviation of the solid line reaches a stable value within 10 iterations, whereas the dotted line reaches a stable value only after 10 iterations; thus, it can be concluded that the solid line reaches a stable value at a faster rate. **Figure 13** is a comparison of the number of turns of the optimal path at different iterations.

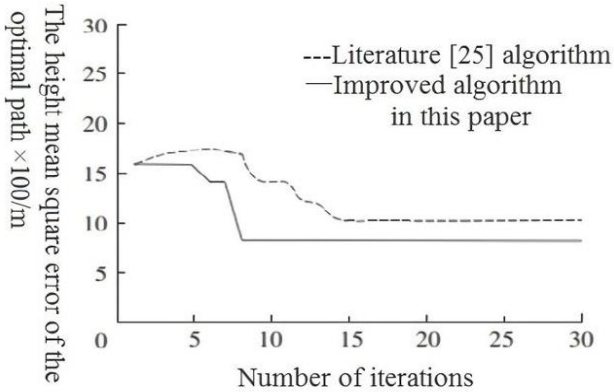

Figure 12. Comparison of mean square deviation of the optimal path height in the 30 × 30 grid environment

As can be seen from **Figure 13**, due to the introduction of the adaptive heuristic function factor, the ants consider the integrity of the path while choosing a path; hence, the solid line is relatively flat, and its does not fluctuate excessively.

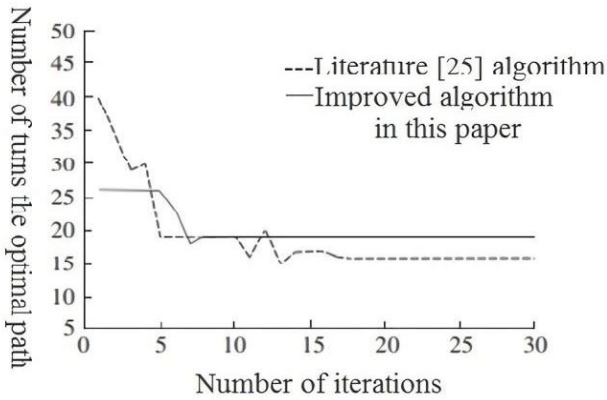

Figure 13. Comparison of the number of turns of the optimal path in the 30 × 30 grid environment

Figure 14 is a comparison of the comprehensive index and average comprehensive index of the optimal path at different iteration times. The lower the index, the better the algorithm. As can be seen from the figure below, the comprehensive index curve of the optimal path of the improved algorithm is relatively flat and tends to a stable value earlier with the increasing number of iterations.

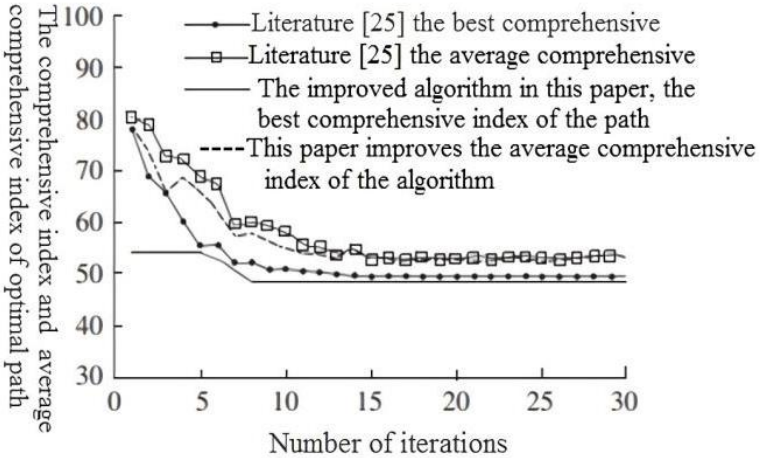

Figure 14. Comparison of the comprehensive indicators of the optimal path in the 30 × 30 grid environment

Based on the results of the path length, height mean square deviation, number of turns, comprehensive index, and iteration times, it can be seen from **Table 3** that the path length found by the improved ant colony algorithm is relatively short, and its iteration times are relatively few in regard to its path length.

Table 3. Simulation results of the 30 × 30 grid environment

Optimal path index	Literature [25] algorithm	Improved algorithm in this study
Path length / m	47.8	46.6
Height means square error / m	10.260	8.225
Number of turns	16	19
Comprehensive index	49.51	48.51
Number of iterations of path length	14	8
Optimal path length average	49.1867	46.0267
Optimal path length variance	40.040774327	5.693385127

6. Conclusion

When ants look for paths in the grid environment, the distance from the current grid to its adjacent grid is not exactly the same. In order to accurately consider the influence of path length on the selection of the following grid by the ant colony, the Euclidean distance from the current grid to its adjacent grid is added to the heuristic function in this study; in addition, this study increases the influencing factors of the heuristic function, forms a closed-loop feedback, and introduces the adaptive heuristic function factor into the transition probability. The distance from the starting point to the grid and finally to the destination point is taken as one of the factors affecting the transition probability of ants in their selection of the next grid, which increases the consideration of the overall environment, improves the pheromone and the pheromone volatilization factor, as well as reduces the impact of excessive or insufficient pheromones in their path selection, thus preventing ants from falling into the local optimum in the search process.

In this study, the improved algorithm enhances the efficiency of search path. From the results, it can be appreciated that the improved algorithm decreases the length of the path, reduces the number of iterations, makes the path smoother, generates a more stable curve, and aids in reaching a stable value more rapidly. Adaptive multi-heuristic ant colony algorithm reduces the comprehensive index and average comprehensive index of UAV path planning.

In this study, the three-dimensional environment of UAV is projected as two-dimensional for research, which simplifies the flight environment. In the future, the complexity of the flight environment needs to be magnified to improve the practical application of the algorithm.

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References

[1] Tang L, Hao P, Zhang X, 2019, An UAV Path Planning Method in Mountainous Area Based on an Improved Ant Colony Algorithm. Journal of Transportation Systems Engineering and Information

Technology, 19(1): 158-164.

[2] Chen Y, Luo G, Mei Y, et al., 2016, UAV Path Planning Using Artificial Potential Field Method Updated by Optimal Control Theory. International Journal of Systems Science, 47(6): 1407-1420.

[3] He Y, 2018, UAV Route Planning Based on Improved Dynamic Weighted A* Algorithm. Journal of Hebei University of Science and Technology, 39(4): 349-355.

[4] Zhen R, Zhang C, Jiao Y, et al., 2019, Research on UAV Route Planning Based on Adaptive Polymorphic Ant Colony Algorithm. Journal of Hebei University of Science and Technology, 40(6): 526-532.

[5] Wang Q, Ma L, Deng H, 2013, Adaptive Path Planning of the UAV Based on Genetic Algorithm. Computer Systems & Applications, 22(1): 200-203.

[6] Xiong H, Yu B, He C, 2020, UAV Path Planning Method Based on Improved PSO. Computer Measurement & Control, 28(2): 144-147.

[7] Wang GG, Chu HCE, Mirjalili S, 2016, Three-Dimensional Path Planning for UCAV Using an Improved Bat Algorithm. Aerospace Science and Technology, 49: 231-238.

[8] Miao H, Tian Y, 2013, Dynamic Robot Path Planning Using an Enhanced Simulated Annealing Approach. Applied Mathematics and Computation, 222: 420-437.

[9] Wu X, Xu L, Zhen R, et al., 2019, Dynamic Step BHRRT UAV Path Planning Algorithm. Journal of Hebei University of Science and Technology, 40(5): 414-422.

[10] Zhao J, 2020, Unmanned Air Vehicle Route Planning Strategy Based on D* Algorithm Extension Guided by Inspiration Point. Machinery Design & Manufacture, 2020(2): 153-157.

[11] Xu J, Liu L, 2019, 3D Trajectory Planning for UAV Based on Improved Artificial Fish Swarm Algorithm. Computer Engineering and Design, 40(2): 540-544.

[12] Cheng Z, Li D, Gao Y, 2019, UAV Three-Dimensional Path Planning Based on the Grasshopper Algorithm. Flight Dynamics, 37(2): 46-50.

[13] Yu S, Wu H, Ma J, 2018, Path Planning for Unmanned Air Vehicle Based on Chaotic Glowworm Swarm Optimization. Machinery Design & Manufacture, 2018(11): 113-116.

[14] Lu T, Liu L, He Y, et al., 2020, Multi-UAV Path Planning Algorithm and Key Technology. Tactical Missile Technology, 2020(1): 85-90.

[15] Xiao Z, Wang P, Leng S, et al., 2016, Research on the Double Precision Mission Planning in Multi-UCAV System. Tactical Missile Technology, 2016(3): 53-57.

[16] Zhu L, Shen C, Shen B, et al., 2019, A Survey of Intelligent Optimization Algorithms for UAV Route Planning Group. Digital Technology and Application, 37(8): 126.

[17] Wang H, Hu X, 2020, Research on UAV Trajectory Planning Based on Ant Colony Algorithm. Science and Technology Information, 18(10): 29-30.

[18] Liu R, Yang F, Zhang H, 2018, Path Planning for UAV Based on Improved Chaotic Ant Colony Algorithm (CACA). Command Information System and Technology, 9(6): 41-48.

[19] Zhang S, Pu J, Si Y, et al., 2020, Survey on Application of Ant Colony Algorithm in Path Planning of Mobile Robot. Computer Engineering and Applications, 56(8): 10-19.

[20] Wang Q, Liu M, Ren W, et al., 2019, Overview of Common Algorithms for UAV Path Planning. Journal of Jin University (Information Science Edition), 37(1): 58-67.

[21] Huang L, Qu H, Ji P, et al., 2016, A Novel Coordinated Path Planning Method Using K-Degree Smoothing for Multi-UAVs. Applied Soft Computing, 48: 182-192.

[22] Tao J, Wang Y, Yang H, et al., 2016, Proceedings of the 28th Chinese Control and Decision Conference (2016 CCDC), May 26-28, 2016: Three-Dimensional Path Planning of Unmanned Aerial Vehicle Under Complicated Environment. IEEE Industrial Electronics (IE) Chapter, Yinchuan, China.

[23] Sun G, Su Y, Gu Y, et al., 2019, Path Planning for Unmanned Surface Vehicle Based on Improved Ant Colony Algorithm. Control and Decision, 36(04): 0839. DOI: doi.org/10.13195/j.kzyjc.2019.0839

[24] Huang X, Xiang Y, 2019, Simulation Research on UAV Route Planning Based on Improved Ant Colony Algorithm. Urban Geotechnical Investigation & Surveying, 2019(1): 83-87.

[25] Li L, Li H, Shan N, 2019, Path Planning Based on Improved Ant Colony Algorithm with Multiple Inspired Factor. Computer Engineering and Applications, 55(5): 219-225.

[26] Chen J, Huang W, Wang X, et al., 2020, Research on Path Planning Based on an Improved Ant Colony Algorithm for Mobile Robot. Chinese High Technology Letters, 30(3): 291-297.

[27] Akka K, Khaber F, 2018, Mobile Robot Path Planning Using an Improved Ant Colony Optimization. International Journal of Advanced Robotic Systems, 15(3): 1-7.

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Application of Technology in the Fault Diagnosis of Large Centrifugal Pump Units

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Abstract: In order to promote the stability of centrifugal pump units and maximize the role of centrifugal pumps, this paper analyzes the composition and basic working principle of centrifugal pumps, presents the main concerns of centrifugal pump maintenance, and finally investigates the common faults and maintenance methods of centrifugal pumps for reference.

Keywords: Centrifugal pump; Fault diagnosis; Detection technology; Daily operation and maintenance

Online publication: April 13, 2022

1. Introduction

As a type of fluid transportation equipment, centrifugal pump units play an important role in pipeline oil transportation production and the petrochemical industry's power hub. The centrifugal pump unit is distinguished by the following characteristics: large volume, with a weight of more than 100,000 tons; high energy consumption; high cost, with a single unit costing more than 100,000 yuan. Therefore, the management level of a centrifugal pump unit is directly related to the safety, stability, efficiency, and energy consumption of oil transportation production. It is particularly important to gauge and understand the common faults of centrifugal pump units [1].

2. Structural composition and basic working principle of centrifugal pumps

2.1. Structure composition

Centrifugal pumps comprise of six parts.

(1) Impeller

As the core component of centrifugal pumps, it has remarkable characteristics, such as high speed and large output. Based on the important role of blades on the impeller, the static balance test needs to be carried out before assembly. The inner and outer surfaces of the impeller should be smooth to effectively reduce the friction loss caused by water flow.

(2) Pump body

The pump body is also known as the "pump shell." it is the main component of the water pump, which mainly plays the role of support and fixation. It is closely connected to the support for installing the bearing.

(3) Pump shaft

The primary function of the pump shaft is to effectively connect the coupling to the motor and transmit the torque of the motor to the impeller. Therefore, it can be used as a key component to transfer mechanical energy.

(4) Seal ring

The seal ring is also known as the "leakage reducing ring." It primarily serves as a sealant [2].

(5) Stuffing box

It is made of packing, which prevents water in the pump from leaking into the surrounding environment and the outside air from entering the pump, thereby maintaining the vacuum state in the pump. The pump shaft and packing generate heat under friction. A water seal tube must be used to inject water into the water seal ring to cool the packing.

(6) Axial force balancing device

When the centrifugal pump is running, liquid is placed at the impeller position under low pressure and flows out under high pressure, resulting in unequal pressure on the left and right sides of the impeller, which effectively generates axial thrust pointing to the inlet position, causing the rotor to move axially and resulting in wear and vibration [3,4]. Therefore, it is necessary to set the axial thrust bearing to balance the axial force.

2.2. Working principle

The rotation of the impeller in a centrifugal pump causes the centrifugal pump equipment to operate under the condition of the centrifugal movement of water. Before turning on the water pump, it is necessary to ensure that the water in the pump shell and suction pipe is full. Starting the motor will cause the pump shaft to drive the impeller and water to rotate at high speed. Water is cast out by centrifugal force to the outer edge of the impeller and flows into the water pressure pipe of the pump via the flow channel of the volute pump housing [5,6].

3. Key points in the daily operation and maintenance of centrifugal pumps

3.1. Key points in the daily operation of centrifugal pumps

The key components of the pump body include the bottom valve, suction pipeline, and mechanical pressure pipe in the mechanical system of a centrifugal pump. With long-term use, the mechanical pressure intensity of the pump body will gradually weaken. Some mechanical operators do not operate and use the centrifugal pump correctly, resulting in damage to the bearing connector, body valve, and body shell, thus affecting the service efficiency of the centrifugal pump [7-9]. Therefore, in the entire operation of centrifugal pumps, mechanical operators must accurately grasp the key points in the operation of centrifugal pumps. Operators and users of centrifugal pumps must exercise reasonable control over the mechanical operation intensity, prevent the mechanical body structure of centrifugal pumps from being damaged caused by excessive mechanical operation intensity, and strengthen the protection of the mechanical system [10].

3.2. Key points in the maintenance of centrifugal pumps

Connecting bearings are found in the mechanical system of centrifugal pumps. The bearings of the pump body should be lubricated and maintained on a regular basis; otherwise, the wear and corrosion of these bearings will be accelerated. The working space environment of the centrifugal pump itself has high liquid corrosivity due to the strong acidity of the petrochemical liquid transported by the centrifugal pump. In this case, the maintenance personnel must pay full attention to the lubrication of the connecting bearings of the centrifugal pump, the bottom plate of the pump body, and the shell of the pump body, so as to ensure the operation flexibility of the mechanical parts of the centrifugal pump. In addition, the operation and maintenance personnel should also pay attention to replacing the mechanical parts of the pump body that have corroded. It is important to replace the mechanical parts of the pump body that have lost their normal operative functions, in order to prevent mechanical failure [11-14].

Enterprise technicians should install network intelligent automatic monitoring devices at certain parts of the mechanical infrastructure to monitor the operation in real time. If abnormal operations of the centrifugal pump device and equipment can be timely detected by the technical personnel, it is critical to immediately identify the inducing factors and carry out necessary treatment. The enterprise's technical personnel should perform all-around daily maintenance and supervision of the centrifugal pump facilities, perform necessary lubrication treatment for the centrifugal pump facilities, and replace centrifugal pump components with safety performance risks on a regular basis. Optimizing the start-up mode of centrifugal pump is conducive to reducing the operation cost of mechanical start-up and stop, and it plays an important role in promoting the smooth start-up and stop of the centrifugal pump device system. The centrifugal pump operation control personnel should thoroughly test the centrifugal pump equipment's lubricating oil device, circulating water device, and pump body bottom plate to ensure that the vacuum state of the shaft seal meets the qualified standard, as well as thoroughly optimize the centrifugal pump's existing start and stop control mode.

4. Maintenance of large centrifugal pump units

In order to effectively deal with the faults of large centrifugal pump units and ensure good operation, these centrifugal pumps need to be overhauled. Relevant maintenance strategies are discussed in this section.

4.1. Mechanical seal

During the operation of large centrifugal pump units, if the sealing ring fails, the performance of the sealing ring material in high-temperature medium will be potentially threatened, which will lead to the failure of the mechanical seal and affect the application effect of centrifugal pumps in mechanical and chemical production. For such faults, there are several maintenance measures that can be taken.

(1) Combined with the functional characteristics of the sealing ring, it is necessary to replace the damaged materials on time and implement the troubleshooting of the centrifugal pump's sealing ring in place, so that the sealing ring can play its role in the operation of the large centrifugal pump unit and avoid affecting the implementation effect of the corresponding production plan.

(2) In the troubleshooting of a large centrifugal pump unit's sealing ring fault, measures such as using inorganic pasting sealant, adjusting interference amount, and improving ring seat material can be taken to eliminate the fault, ensuring more reliable sealing ring performance and providing support for the efficient operation of the large centrifugal pump unit.

(3) During the maintenance of large centrifugal pump units, in regard to component failure caused by welding heat treatment, corrosion-resistant and high-temperature resistant alloy materials should be used by maintenance personnel to replace the failed components in time. After maintenance, the performance of the components should be evaluated to gauge the operation of the centrifugal pump under the action of the sealing ring, so as to improve the maintenance effect of petrochemical enterprises and avoid potential safety hazards in the operation [15].

4.2. Abnormal noise

Noise or abnormal vibration of large centrifugal pump units during operation will threaten the safety performance of centrifugal pumps and increase the incidence of operation failure [16]. For such faults, petrochemical maintenance personnel are required to carry out corresponding maintenance work to effectively deal with the abnormal sound faults. Several measures can be taken to deal with these faults.

(1) The centrifugal pump should be shut down immediately to ensure that the impeller is balanced, and the pump shaft and motor shaft are concentric. At the same time, it is necessary to thoroughly inspect whether the large centrifugal pump unit's foundation is firm and whether the rotor rotates in balance. Effective

response work should be implemented to avoid adverse impact on the working performance of large centrifugal pump units.

(2) When dealing with abnormal sound faults during the operation of centrifugal pumps, petrochemical maintenance personnel also need to consider whether the centrifugal pump inhales sundries and whether cavitation occurs at the impeller inlet. In case of these occurrences, they should be eliminated in time with the support of highly-targeted fault treatment, so as to ensure the effectiveness of the treatment in the petrochemical industry and provide support for improving its operation level.

4.3. Other parts

(1) Maintenance for motor failure

If rotor overload and rotor eccentricity occur during the operation of large centrifugal pump units, the failure rate of the centrifugal pump motor increases, and its working performance suffers, necessitating treatment by maintenance personnel. Among them, when overhauling and dealing with the overload operation fault of the rotor, it is necessary to consider whether the rotating parts have friction problems, realize the disassembly of the pump body, and provide a reliable guarantee for the performance optimization of the rotating parts. At the same time, with the support of the valve control mode, the operation parameters of large centrifugal pump units should be controlled within the design range to meet the requirements of a stable operation. When eliminating the eccentric operation fault of the rotor, petrochemical maintenance personnel need to determine whether the pump has geometric eccentricity or impeller blade vibration, actively adjust the rotor load, and timely eliminate the exciting force caused by eccentricity with the support of comparative test, so as to realize the treatment of centrifugal pump motor fault.

(2) Maintenance for centrifugal pump impeller fracture

During the use of large centrifugal pump units, if the material performance reliability of the impeller is insufficient and the long-term operation exceeds the fatigue strength, coupled with the stress concentration at the scratch caused by the friction between the impeller and the pump shell, the impeller will be affected by additional stress during use, which indirectly increases the incidence of fracture [17]. In light of this failure, petrochemical enterprise maintenance personnel must consider whether the material performance is reliable and whether the stress conditions of high-speed operation are satisfactory based on an understanding of the functional characteristics of centrifugal pump impellers. They should then carry out effective response work to realize the timely treatment of centrifugal pump impeller failure.

4.4. Balancing device

The most important operation of large centrifugal pump units is centrifugation. Its main function is to separate liquid through centrifugal force, so as to extract useful parts, separate impurities, and maximize the use of raw materials. If a large centrifugal pump unit is to function normally, it cannot rely solely on the pump shaft and impeller. The balancing device is also an important component that plays a vital role in the entire production process. If the balancing device fails, the large centrifugal pump unit will not function normally. The balance disc is the most easily damaged part of the balancing device when the equipment is running. The balance disc is often worn due to centrifugal force [18]. If the wear is serious, it will affect the balance of the entire device. Therefore, it is necessary to maintain the balance of the device and replace the balance disc regularly. In order to further reduce the wear of the balance disc, the frequency of replacement, and the maintenance cost, gaskets can be added on the balance disc to prolong its service life.

4.5. Pump shaft

The pump shaft is an important part of the large centrifugal pump unit, and it should be paid attention to during maintenance. During the operation of large centrifugal pump units, the pump shaft rotates at high speed, which produces strong centrifugal force through the cooperation between the pump shaft and the rotor, relies on the engine, and provides power through the rotor. The impeller installed on the bearing is rotated at high speed to separate the liquid [19,20]. The liquid of varying qualities is layered, and finally the effective components and the impurities are separated. Due to the high-speed rotation, the pump shaft will inevitably wear, and various faults will occur under the centrifugal force. Therefore, in order to ensure a normal operation, it is necessary to carry out regular maintenance, focus on the inspection of the pump shaft, and replace the damaged parts in time, so as not to disrupt the entire production process and jeopardize the interests of enterprises.

5. Conclusion

In conclusion, the common faults of large centrifugal pump units involve the mechanical seal, balancing device, pump shaft, abnormal noise, and other faults. Ensuring the proper operation of centrifugal pump units can help the industry grow. The stable operation of centrifugal pump units can also improve production efficiency, thereby driving the development of the industry and enterprises. It is particularly important to strengthen the daily maintenance and inspection of centrifugal pump units as their service life can be extended with regular maintenance and inspection.

Disclosure statement

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References

[1] Wang R, 2022, Use, Maintenance, Overhaul and Troubleshooting of Centrifugal Pumps. Scientific and Technological Innovation and Application, 12(04): 121-123.

[2] Tao H, Lan W, 2020, Overhaul and Lubrication Seal Transformation of a Type of Multistage Centrifugal Pump. Equipment Management and Maintenance, 2020(21): 108-109.

[3] Wen Q, Wang Y, 2020, Development of Vibration Detection System for Plastic Centrifugal Pump Shaft Based on LabVIEW. Journal of Xinxiang University, 37(09): 60-64, 73.

[4] Zhang Y, 2020, Development of Vibration Detection System for Plastic Centrifugal Pump Shaft Based on LabVIEW. China Equipment Engineering, 2020(16): 159-160.

[5] Zhe M, Jia G, Shui G, et al., 2020, Review of Internal Flow Structure, Performance Optimization and Fault Detection of Centrifugal Pumps. Journal of Zhejiang University Science A (Applied Physics and Engineering), 21(02): 85-117.

[6] Li H, Zhu G, 2019, Design and Implementation of Vacuum Testing System for Centrifugal Pump in Water Supply System. Electrotechnical, 2019(24): 168-172.

[7] Jiao X, 2019, Analysis of Key Points of Daily Maintenance of Chemical Machinery and Equipment. Chemical Management, 2019(24): 111-112.

[8] Jiang L, Wu X, Li Y, 2019, Application of Detection Technology in Fault Diagnosis of Large Centrifugal Pump Unit. Equipment Management and Maintenance, 2019: 162-15.

[9] Yang K, 2018, Centrifugal Pump Fault Detection and Elimination. Chemical Design Communication, 44(07): 118.

[10] 2016, National Electric Submersible Centrifugal Pump Quality Supervision and Inspection Center. Collection of Oil Production Engineering, 2016(02): 2, 107.

[11] 2016, National Electric Submersible Centrifugal Pump Quality Supervision and Inspection Center. Collection of Oil Production Engineering, 2016(01): 2, 87.

[12] Zhao G, 2015, Discussion on Detection and Maintenance of Common Faults of Centrifugal Pumps. Chemical Management, 2015(11): 37.

[13] Liu F, Liu F, Sun G, et al., 2012, Discussion on Common Fault Detection and Maintenance of Multistage Centrifugal Pump. Intelligence, 2012(20): 36.

[14] Xie D, 2009, Application of Vibration Detection in High Temperature Centrifugal Pump Installation. Petrochemical Technology and Economy, 25(04): 43-46.

[15] Liu Z, Che Q, 2008, Research on On-line Detection and Alarm System of Primary Cavitation in Centrifugal Pump. Fluid Machinery, 2008(02): 47-50.

[16] Wang L, Zhao J, 2008, Research on On-line Detection System for Operating Parameters of Centrifugal Pump. Journal of Shandong University of Architecture, 2008(01): 34-37, 60.

[17] Deng X, 2007, Evaluation of Uncertainty in Noise Detection of Multistage Centrifugal Pump. Machinery Manufacturing, 2007(06): 68-70.

[18] Chen X, 2021, Analysis of Mounting Hole Maintenance for Mechanical Seal of Multistage horizontal Centrifugal Pump. China Equipment Engineering, 2021(15): 48-49.

[19] Qi W, Jin Y, 2021, Failure Causes of Mechanical Seal Structure of Centrifugal Pump and Feasible Suggestions for Maintenance and Transformation. Farm Machinery Using & Maintenance, 2021(05): 81-82. DOI: 10.14031/j.cnki.njwx.2021.05.038

[20] Gu Y, 2019, Discussion on Multi-stage Centrifugal Pump Maintenance, Common Fault Analysis and Treatment Method. Nanfang Agricultural Machinery, 50(14): 171-172.

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Application of Smart Lighting in Urban Street Lighting

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Abstract: At present, the number of road engineering projects is increasing, and the corresponding street lighting work is receiving much more attention. In order to improve the lighting, operation, convenience, and energy-saving effect of urban streets, the concept of "smart lighting" needs to be implemented. This includes the planning of an urban street lighting design scheme and the use of appropriate software as well as components to realize significant optimization of the lighting work in urban streets. Therefore, this paper discusses the application measures of smart lighting in urban street lighting to provide reference.

Keywords: Smart lighting; Urban street lighting; Application measures

Online publication: April 13, 2022

1. Introduction

The development of urban streets reflects the level of urbanization, whereas the development of urban street lighting systems reflects the city's overall construction level. The application of the smart lighting concept and it corresponding systems to urban street lighting can promote the overall optimization of the urban street lighting system, which will not only improve the lighting effect of urban streets and the level of urbanization, but also realize the convenience of operation as well as the effect of environmental protection. Therefore, the application effect of smart lighting in urban street lighting is favorable, and this field of research is of great significance.

2. Design scheme of urban street lighting

2.1. Installation design

During the installation design of urban street lighting, if 70 W lamps are used, the distance between lamps and poles should be 1.5 meters and 7 meters from the ground. If 150 W lamps are used, the distance between lamps and poles should also be 1.5 meters, but 10 meters from the ground. At the same time, the distance between two adjacent light poles should be fixed at 10 meters to improve the rationality of urban street lighting and ensure that the environment for driving at night is safer and more comfortable.

2.2. Brightness uniformity

Brightness uniformity refers to the uniform effect of street lamps projected onto the ground within a lighting range. With the help of an instrument, it can test up to 100 points. If the minimum brightness is 10 and the average brightness is 20, the uniformity is 0.5. In assuming uniformity as an important basis for light

distribution, the larger its value, the more scattered the light is, and the better the lighting effect.

3. Smart lighting system in urban street lighting

At present, China's economic level is improving and the process of urbanization is accelerating. The city's development level, as an important environment for people's living and life, has a significant impact on the production as well as the living state and quality of the people. Therefore, the development of "smart cities" and "green cities" has become the main trend in urban development. In terms of urban road traffic, it is very important to fully optimize the lighting system, which requires the application of smart lighting concepts and systems in line with the urban development trend. In fact, the smart lighting system is not a single process, but a scientific system layout. It is necessary to elucidate the significance of urban street lighting in relation to the city's overall development needs in order to ensure people's travel safety and improve the overall road traffic operation effect. Moreover, the thorough implementation of the smart lighting system in urban street lighting will not only effectively meet the aforementioned needs, but also further promote the development of science and technology in China. At present, smart technology, network technology, 4G technology, and 5G technology are all becoming increasingly popular. Applying them to the development of smart cities and effectively implementing smart lighting systems can accelerate the development of corresponding software and optimize the overall layout, so as to improve the application effect of smart lighting system in urban street lighting and promote the development of smart cities [1].

4. Urban smart street lamp design

In line with smart city construction, the faster its development speed, the higher the requirements for smart lighting in urban street lighting. Ensuring the rational application of smart lighting systems is not only conducive to the further development of smart cities, but also provide a guarantee for the safety of people driving at night. Therefore, it is important to pay attention to the design of smart lighting system in urban street lighting.

4.1. Street lamp planning

Street lamp planning is the core component in the smart lighting system. In the process of street lamp planning, it is necessary to first understand the requirements of urban street lighting for street lamps, propose diversified design and planning schemes according to the requirements, establish a planning model with the assistance of building information modeling (BIM), and modify the design and planning contents in line with the actual situation of urban streets. BIM is used to simulate the actual application of the design and planning contents to validify their rationality and avoid the waste of resources.

4.2. Design and implementation

On the basis of ensuring the scientificity and rationality of the design and planning scheme, the smart lighting design can be applied. BIM is used to confirm the contents of the scheme and improve each aspect in detail, optimize the control information to improve the convenience of smart lighting control, as well as provide reasonable conditions for smart operations in accordance to the database, so as to improve the application effect of smart lighting [2].

4.3. Detection technology

The main purpose of using the detection technology in the smart lighting system is to improve the rationality of smart lighting.

(1) It is necessary to inspect the working environment of the smart lighting system to understand the control terminal equipment, host, controller software, and network conditions, so as to avoid adverse conditions in the constituent system.
(2) Detecting the communication interface in the smart lighting system and confirming that the communication state is normal can improve the performance and effect of the smart lighting system. Generally, the application effect of the interface should be mastered through testing.
(3) The test is completed by testing the data processing ability and confirming that the applied software meets the relevant standards [3].

5. System implementation

5.1. Mobile monitoring software

In urban street lighting, the use of mobile phone monitoring software is an important component of the smart lighting system [4]. At present, mobile phones have become an indispensable part of people's daily life and production. They are not only functional, but also important. Some jobs even require that "mobile phones do not leave hands." It can be appreciated that the use of mobile phone monitoring software can improve work efficiency and convenience [5]. In the course of their work, employees, under the smart lighting system of urban street lighting, can control the software by using their mobile phones to carry out smart lighting monitoring. Upon discovering any sort of fault, they must promptly check and tend to the working state of street lamps through the application management center and the remote intelligent network, as well as promptly identify adverse conditions, in order to ensure the lighting effect of urban streets and optimize the maintenance work, so that the application effect of the smart lighting system in urban street lighting can be improved [6].

5.2. Remote smart street lamp communication system

The current technical composition of remote smart street lamp communication system mainly includes 3G technology, 4G technology, and ethernet technology; 5G technology has not been integrated into it. The grid connection association operation of street lamps can be applied using the smart association control and smart node controller to form a scientific and unified smart control layout [7]. On this basis, each street lamp must be equipped with an smart node controller to collect and transmit data. At the same time, it can comprehensively gauge the network situation and timely adjust the communication requirements, so as to improve the stability of data reception and transmission as well as the application effect of remote smart street lamp communication system in smart lighting [8].

5.3. Remote smart data processing center

After completing the construction of the smart lighting system, the remote smart data processing center can be used to carry out data processing, including the monitoring interface of street lamp status, the comprehensive street lamp information prompt interface, and the setting interface of street lamp status. In the work process, information processing can be carried out based on the actual state of street lamps and lighting requirements in the surrounding area. For example, half off, fully off, one-by-one off, and other operations can be implemented, and adjustments can also be made for single light intensity, double light intensity, light color, and other aspects, so that the lighting effect can meet the requirements of street lighting as much as possible in line with the actual situation and traffic status [9]. At the same time, the operation of street lamps in the city can be displayed in real time on screen at the control center. The remote smart data processing center can store and manage relevant data using online technology and cloud technology; these data can then be extracted and analyzed when necessary, so as to provide a basis for the rational application and continuous optimization of urban road smart lighting system from a long-term

perspective [10].

6. Urban road lighting and energy-saving design

6.1. Light source selection

In order to effectively reduce the energy consumption of the urban road smart lighting system, it is crucial to choose a light source wisely in the application process to ensure its rationality and environmental protection effect. In fact, there are many types of lamps that can be used in urban street lighting, and different lamps correspond to different light colors and brightness. At the same time, different lamps have different specifications and parameters. Therefore, the selection of light source should be based on the actual lighting requirements of streets in various urban environments [11]. Based on the current lighting requirements of most urban streets, it is necessary to use LED light sources to achieve a synchronous effect of lighting and environmental protection. This type of light source does not only bring about good lighting effects, but also meet the demand for high efficiency, energy saving, and environmental protection. In general, when using LED lamps as the light source for urban streets and placing them under the same lighting effect, the degree of electric energy savings is around 80%, which significantly reduces the cost amounted in the process of urban street lighting while also reflecting good environmental protection benefits [12].

6.2. Lamp performance

The use of LED lamps as the primary light source for urban street lighting requires careful consideration of its actual use effect while also improving environmental protection benefits. Currently, the effective efficiency of LED lamps that are widely used in China is about 150-160 Im/W, but the effective efficiency of traditional sodium lamps is about 70-75 Im/W over the same period of time. Therefore, it concludes that the use effect of LED lamps is better [13]. At the same time, the bat airfoil light distribution function in LED lamps can realize the light intersection between two adjacent street lamps, thus preventing dark lighting areas and further improving the lighting effect of urban streets. In addition to that, LED lamps also provide a good level of protection. Under normal circumstances, their dust-proof and waterproof densities are relatively high, allowing them to fully meet the requirements of urban street lighting [14].

6.3. Energy-saving ballast

In the process of designing a smart lighting system for urban street lighting, the use of ballasts should be fully considered. Generally, ballasts have several advantages.

(1) Energy saving

A ballast of about 60 Hz should be used as it can improve the lighting effect by about 10% and reduce the power by about 20% [15].

(2) Stability

The use of ballast reduces the possibility of stroboscopic conditions in the lighting system, thus improving the overall stability of urban street lighting. Drivers driving at night can benefit from a better resolution environment and a lower risk of visual fatigue.

(3) Reliable

The operation process of the urban street lighting system is more stable with the use of ballast, and the lamps can also be preheated to improve the lighting efficiency when the system is turned on [16].

(4) Design methods

In the process of designing the smart lighting system in urban street lighting, the design must be optimized in order to improve its energy-saving effect [17]. Designers are required to collect relevant and comprehensive data from every aspect, understand the particularity of urban street lighting based on

professional theories, and use it as the basis to refine the design scheme. At the same time, they should also be able to grasp relevant information about urban street structure and plane conditions, so as to reasonably control the spacing of lamps and improve the utilization rates of various resources while ensuring the lighting effect. When designing the circuit, it is necessary to select the most suitable position for the incoming line and power supply based on the surrounding environment, in order to provide a guarantee for the safety of driving at night [18]. In addition, it is also important for designers to implement energy-saving designs based on the on and off times of street lamps, the amount of sunlight during the day, and seasonal changes, in order to improve the lighting system's energy-saving effect. Other than that, there should be two control modes in the system – automatic control and manual control. The automatic control mode should be applied on a daily basis, whereas the manual control mode should be applied under certain circumstances, so as to fully meet the lighting requirements of urban streets and control the energy consumption.

7. Urban street lighting maintenance

In order to ensure the lighting effect of urban streets, it is necessary to pay attention to the maintenance of lamps. If a lamp fails to function and is not repaired in time, the light intensity will reduce, thus affecting the lighting effect in the surrounding area [19]. As a result, not only is it difficult to ensure the safety of driving at night, but there is also a waste of electric energy. Therefore, relevant staffs must pay close attention to the maintenance of lamps, regularly carry out urban street lighting system maintenance in a comprehensive manner, as well as timely identify and address the errors [20]. In addition, UV resistant lampshade or impact resistant materials should be used to reduce the probability of failures and prolong the service life of lamps, which can help with energy conservation, environmental protection, and cost reduction.

8. Conclusion

Road traffic plays an important role in the process of urban construction and development, and urban street lighting has been receiving much more attention. Under the background of sustainable social development, the use of smart lighting in urban street lighting has emerged as the main development trend. Therefore, in the construction of urban street lighting systems, the application of the smart lighting concept and system is conducive to optimizing the development of urban streets. At the same time, it serves as an impetus for promoting the development of smart city systems.

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References

[1] Li X, Xiao Q, He X, 2021, Application of Intelligent LED Lamp in Urban Road Lighting. Electromechanical Engineering Technology, 2021(7): 259-260, 264.

[2] Wu J, 2021, Application of Smart Light Poles in Smart Cities. Engineering Technology Research, 6(17): 124-125.

[3] Gao Y, 2020, Key Technology Research and Application of Smart City Road Lighting System. Electronic World, 24(14): 161-162.

[4] Deng B, Jin Z, Wang J, 2020, Optimization of Intelligent Road Lighting System Based on NB-IoT Technology. Journal of Lighting Engineering, 31(5): 137-141.

[5] Zhang H, Wu Y, Feng Z, et al., 2020, The Role of Smart Lighting application in Smart City. Journal of Lighting Engineering, 31(5): 67-77.

[6] Liu Q, Zhang X, Gao J, et al., 2019, Key Technologies of Internet of Things for Urban Road Intelligent Lighting. China Illuminating Engineering Journal, 30(4): 13-16, 47.

[7] Chen Z, Chen J, 2021, Application of DC Power Supply Intelligent Lighting System in Road Lighting. Electronic Production, 28(18): 86-87.

[8] Li J, 2021, Application of Intelligent Control System for Urban Road Lighting. Integrated Circuit Applications, 38(9): 108-109.

[9] Duan X, 2020, Penetration of Intelligent Transportation in Urban Road Design. Science and Technology Innovation, 17(34): 165-166.

[10] Tan J, 2021, Multi-Rod Integration and Intelligent Design in Urban Road Lighting. Intelligent Building and Smart City, 29(1): 115-116.

[11] Jin X, 2021, Analysis on the Leading Role of Smart Lighting in Smart City Construction. Urban Lighting, 25(4): 16-17.

[12] Zhang L, Wang P, He X, 2020, Detection and Analysis of Road Lighting Energy Saving Transformation. Light Source and Illumination, 29(2): 9-12.

[13] Yang N, 2020, Innovation and Practice of Highway Inclement Weather Protection Working Mode Supported by Road Intelligent Maintenance Management System. Urban Public Transport, 27(5): 25-28.

[14] Cai W, Peng Z, 2021, Design and Research of Urban Road Lighting Asset Management System. Urban Lighting, 25(4): 50-53.

[15] Cai R, 2020, Application of Intelligent Light pole in Road Lighting Reconstruction. Intelligent Building and Smart City, 29(4): 29-30.

[16] Wang H, 2020, Design and Application of Urban Intelligent Lighting Control System. Integrated Circuit Applications, 37(11): 72-73.

[17] Peng J, 2021, Design of Intelligent Control System for Road Lighting Based on Power Carrier Communication. Electrotechnical, 43(8): 104-105.

[18] Xie W, 2021, Design of Intelligent Control System for Road Lighting Based on Power Carrier Communication. Intelligent Building and Smart City, 29(1): 125-127.

[19] Qin Y, 2021, On the Status quo and Integration and Improvement Countermeasures of Intelligent Urban Lighting Management System in Our City. Urban Lighting, 25(4): 39-41.

[20] Zhang B, 2021, Problems and Matters needing attention in Municipal Road Lighting Construction. Intelligent Building and Smart City, 29(7): 171-172.

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Library Archives Management Based on Electronic Technology

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Abstract: In order to better promote the digital and electronic development of libraries, this paper first analyzes the management requirements of library archives, constructs a management mode based on electronic technology, and analyzes the management measures of electronic library archives for reference.

Keywords: Archives management; Library; Electronic technology

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1. Introduction

All kinds of library archives come from educational, scientific research, and management operations. By gathering and exploring this information, readers are able to gauge a library's general state. This is not only to assist readers in comprehending a library's materials, but also to carry out various public relations and educational activities. Readers can comprehensively display the necessary information and the specific situation of the library through the effective implementation of archives management, which is based on comprehensively classifying various information data. This ensures that readers fully understand the internal retrieval system of the library and make rational use of its resources. In addition, as these archives deal with the specific contents and actual situation of various library activities, the research and analysis of these data in the decision-making process is an important basis for library directors to make sound decisions as well as effectively carry out the management work [1-3]. With the continuous change and development of the times, the contents of the library will also change. In the current environment, the library's contents are more vital than ever in order to provide readers with high-quality services. This should be based on the effective implementation of archives management. The purpose of library archives management is to record and properly archive the important documents and activities of the library. The management of these materials and data information can improve the service operation of a library.

2. Library archives management requirements

2.1. Accuracy

Accuracy requirement implies that all documents must be obtained in a short period of time, and the working documents must be able to professionally record specific parameters and information. For example, book files are open to the public and must be accurate. The current storage location of books, including warehouse information, bookshelf information, book type information, and other information, should be recorded. All information must be keyed into the proprietary resource system after comprehensive evaluation. Accuracy is a fundamental factor in library archives management. Even if the hardware and

software systems do not meet the requirements, the accuracy can be improved at the expense of storage efficiency and management norms.

2.2. Timeliness

On the other hand, timeliness requirement implies that all documents should be recorded, analyzed, and stored within a short period of time, especially the need to fulfill these responsibilities and obligations [1]. After entering the location of the library, such as the book type, the content of the first book must be merged immediately, and a new file system should be created. The formed working system has higher reliability. In the rapid demand stage, it is necessary to determine the shortcomings of the existing working mode and upgrade both the hardware and software systems to ensure the stability of the existing working system, a quality implementation, and that the current requirements are met in the task of file management.

2.3. Collaboration

Collaborative requirement implies that when new documents are added to the file management system, the information must be stored in an accurate database and can be readily provided to the public. Considering its actual use and operation, the archives management system can be divided into many forms: book archives, human resource management archives, library operation financial system archives, and so on. This forms a management system that can operate more efficiently. In addition, some management systems deployed with cloud computing need to associate localized files with cloud archives following data storage, in order for the entire file management system's archives to be updated at the same time.

2.4. Improvement

Improvement requirement implies that whether it is a document management system or a task management system, there must be corresponding improvement indicators, including a comprehensive innovation of the existing management mechanism and the continued implementation of the management mode, which can be used by other system users. According to an individual's own needs, the individual can enter the relevant keywords in the management system to obtain the desired file type. The work management system should have high operational efficiency. In the operation and development phase, according to different input instructions and working systems, information is retrieved from the corresponding working database to prevent the database management system from working [4].

3. Library archives management mode based on electronic technology

3.1. Model structure

On the premise of using electronic technology to innovate the working mode of the internal archives management in libraries, a certificate authority (CA) center issuing public key infrastructure (PKI) certificate and an authoritative attribute authority (AA) center with privilege management infrastructure (PMI) technical attribute should be first established. Thereafter, the roles of readers outside the library should be strictly distinguished according to the actual needs of its business development and the readers' access to various archives resources in the library. The scope of authorization for roles like readers is clearly specified. At the same time, it is necessary to establish and improve the role specification and formulate corresponding role specification certificates. Following that, it is important to formally configure the public transport certificate and role assignment issued by the user on the server device and build the LDAP server based on the actual needs of security applications. At the same time, a server for external user identity and authorization verification, as well as a data resource server in the library, must be built.

When an external user has a demand for the application service offered by the library, the actual access request and public key certificate of the external user must be submitted to the authentication server, and

the authentication server must then submit the identity and public key certificate of the library. When external library users visit the authentication server, only those who successfully pass the server authentication task will be able to access the library's data resources. The authentication request is submitted by the authentication module. It should be noted that the reliability and authenticity of the digital signature certificate require additional verification, which is mostly done through the public key certificate library and the certificate revocation list (CRL) in the lightweight directory access protocol (LDAP) server. After the certificate is verified, if the server determines that the content of the certificate does not meet the relevant preset requirements, the verification server will send an access denial of service information to the user port [5-9].

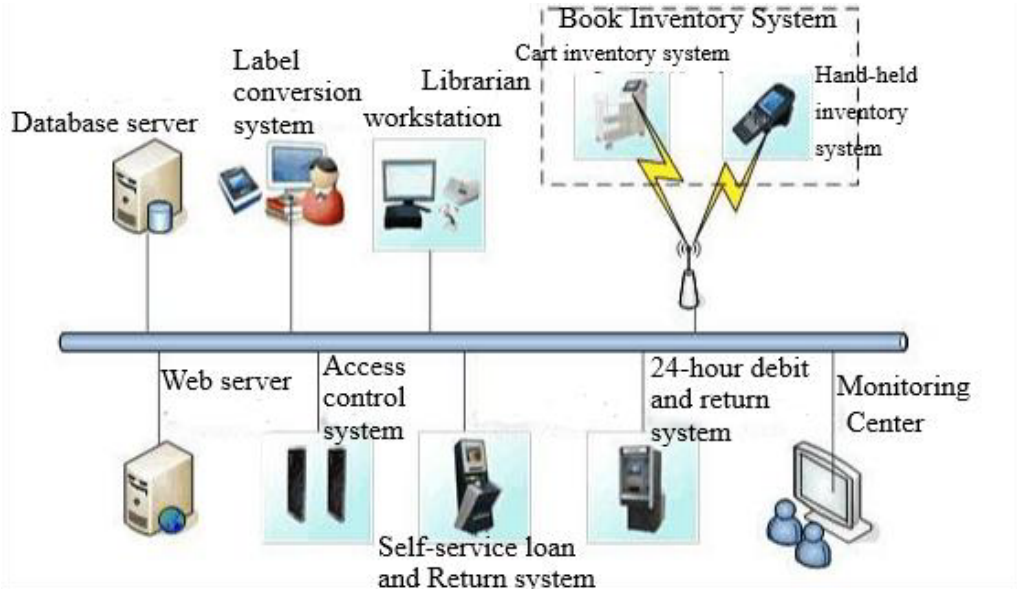

Figure 1. Model structure

After the user has completely passed the identity audit, the next step is to enter the relevant links of permission verification. The implementation of protocol adaptation requires the assistance of control framework to analyze the acquisition instructions scientifically and comprehensively. After the session is established, the obtained information should be converted accordingly. For example, the format should be specified, and then an interface that meets its return requirements should be provided. Generally speaking, the operation of alarm collection can be triggered through the control framework. The manufacturer's protocol can then be analyzed, followed by the completion of the protocol adaptation operation, realizing it through the callback interface. As the system accepts warning data from a wide range of surroundings, it provides a practical and effective guarantee to the entire operating system through scientific and automated processing. The destroy callback method can be used to erase all the original information of the interface if the system can no longer execute; for example, if it is in a halted state. As the NetFlow protocol does not require polling, it is easy to use. Upon starting the main program, the NetFlow protocol can be automatically collected. The program collects the received data and enters them into the database; then, they are converted into alarm data, transmitted to the upper layer, and processed. Snmptrap will send trap packets without polling. It can accurately analyze the alarm information and complete the writing operation of the database. Under the SNMP protocol, the SNMP interface in the acquisition module will perform snmpget operation, and the agent will quickly package the extracted effective data, convert them into external format, perform the encapsulation operation, and send it to the manager in the form of SNMP package to realize the implementation of protocol adaptation [10].

3.2. Model application

The main contents of the secure sockets layer (SSL) protocol include handshake protocol, ciphertext modification protocol, alarm protocol, and so on. The application of SSL protocol in computer communication network can improve the security and reliability of information transmission.

First, the application of SSL protocol to wireless video surveillance in computer communication technology is introduced. SSL protocol is widely used in the field of video surveillance, such as server, C/S mode, and control system. Different structures play different roles. Server is the core of the communication system. The wireless video monitoring system adopts SSL protocol for video acquisition and playback, and the established information can be transmitted to the database. Using the SSL protocol, the client can select the video path and transmit it to the server at the same time, so as to determine the video stream information. For hardware acquisition, SSL protocol can be used to transmit the collected video stream to the server in real time. Therefore, through the application of SSL protocol, the internal system of computer communication network can be connected, so as to improve the reliability of data transmission [11].

The second is the application content of SSL protocol in web network. The SSL protocol can ensure a secure data transmission channel through coding technology and encryption technology to improve data security. In addition, by using the SSL protocol to encrypt HTTP information transmission and using the public key encryption technology to convert HTTP to HTTPS, it is possible to prevent data loss, omission, and other problems. The data transmission process does not require the installation of any service software when using the SSL protocol, but it does require the completion of the encryption processing of the web browser through the application layer encryption to ensure the security and integrity of information transmission.

4. Library archives management measures based on electronic technology

4.1. Resource management under digital technology

With the development and progress of digital library, various emerging technologies have been applied to the service system of intelligent library. Libraries should use more advanced management systems to manage and optimize library resources. By using servers such as electronic tags, users can set up unique ID codes for themselves to borrow and download resources by using the account password. According to each of their own reading preferences, recommendations will be suggested as big data is used to gauge their preferences as well as carry out corresponding algorithms and processing. Following that, book resources will be recommended based on their needs and various functions such as collection will be provided [8].

4.2. Intelligent system management

In the process of electronic upgrading, the management system of the library should also be reformed and upgraded at the same time. The traditional management system should not be used for modern library management. According to the actual development of different regions, targeted solutions and work plans conducive to the development of local libraries should be proposed. According to the actual work of the library management system, it is crucial to strictly formulate a scientific and reasonable management system, integrate information technology and big data into the management system, use advanced software system to manage electronic library archives, and regularly maintain the software system. Based on advanced technology, the management system can better promote the development and sustainable operation of public libraries [12-15].

4.3. Proper design of interactive functions

The design of interactive functions is one of the most needed functions in electronic library archives. The use of interactive functions can enhance users' interest in reading. The library is one of the most important

places for knowledge transmission, dissemination, and preservation of information interaction. By developing interactive functions, users can express their understanding of their readings, their satisfaction with the contents related to the services offered by the library, and their feedback on the storage of books and archives resources on the interactive platform. The interactive function in the library can better promote the communication among people and the dissemination of knowledge. The password strengthening of dynamic interaction can also promote the construction of electronic library archives [16-20].

5. Conclusion

In conclusion, the application of electronic technology in library archives management can improve the security of electronic library resources, prevent the leakage of core data and information, as well as improve the efficiency of library archives management. In conjunction with the intelligent management system, the quality of library archives management can be substantially improved.

Disclosure statement

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References

[1] Qin X, Huang X, Zhuang H, 2022, Analysis and Enlightenment of Operation Data of O2O Service Platform in University Library – Taking the Book App of Xi'an University of Electronic Science and Technology as an Example. Library Journal, 41(2): 77-83, 88.

[2] Huang Y, 2022, Research on Copyright of Library Electronic Document Delivery Service. Communication and Copyright, 2022(2): 120-124.

[3] Huang D, 2022, Research on the Integrated Management Method of Library E-Books and Book Resources. Modern Vocational Education, 2022(6): 178-180.

[4] Gai Y, 2022, Research on E-Book Management Mode in Asset Management of University Library. Cultural Industry, 2022(1): 100-102.

[5] Wang J, 2021, Research on the Construction of E-Book Resources in Higher Vocational College Library. Inner Mongolia Science, Technology and Economy, 2021(24): 105-106.

[6] Zhao M, 2021, The Role of Big Data Application in Library Management and Service. Lantai Neiwai, 2021(34): 58-60.

[7] Peng Z, 2021, E-Commerce and Digital Library Construction. Age of Wealth, 2021(11): 162-163.

[8] Cheng B, Wu G, 2021, Investigation and Research on the Integration, Disclosure and Management Mechanism of Electronic Resources in University Library. Library Work and Research, 2021(11): 76-83.

[9] Zhao K, 2021, Research on the Innovation of Library Audio-Visual Electronic Resource Cataloging Based on RDA. Library Journal, 40 (11): 72-83.

[10] Bao J, Ning Y, 2021, Application of Cloud Desktop Technology in Reader Computer Management of Public Library – Taking the Upgrading Project of Electronic Reading Service of Anhui Library as an Example. Journal of Henan Library, 41(10): 32-35.

[11] Ju Y, 2020, Application of Electronic Authentication Technology in Library Archives Management. Electronic Technology, 49(4): 64-65.

[12] Xiao LL, Li YZ, 2022, Research on Library Archives Management Under the Background of Big Data. China Newspaper Industry, 2022(2): 48-49.

[13] Zhang S, 2022, Thoughts on the Innovation of Library Archives Management Under the Network Environment. Industry and Technology Forum, 21(2): 265-266.

[14] Cross Country of Thought, 2022, Reading List of Library, Information and Archives Management in 2021. Library And Information Knowledge, 39(01): 148-160.

[15] Lian S, 2021, Research on the Embedded Integration Construction Mode of Archival Information and Library Information Resources. Office Business, 2021(19): 114-115.

[16] Liu H, 2021, New Path of Library Archives Information Management Under the Trend of Internet. Journal of Inner Mongolia University of Finance and Economics, 19(5): 147-149.

[17] Zhu Y, 2021, Analysis on the Path of Library Archives Information Management from the Perspective of Internet. Modern and Ancient Cultural Creation, 2021(36): 105-106.

[18] Lu X, 2021, Research on the Characteristics and Path of Library Archives Data Management Under Big Data Environment. Urban Construction Archives, 2021(8): 31-32.

[19] Wang D, Ma Q, 2021, Analysis of Library Personnel File Management in the Era of Big Data. Office Business, 2021(15): 150-151.

[20] Zhao W, 2021, Optimization Path of Archives Management in University Library. Archives Management, 2021(4): 124-125.

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The Human-Machine Safety Design of Mechanical Toys for Children

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Abstract: In order to ensure the safety of children while using machineries and avoid harm caused by mechanical toys, this paper analyzes the types and detection standards of children's toys, discusses the reasons for the harm caused by these toys, and proposes human-machine safety design strategies for children's toys as reference.

Keywords: Mechanical toys; Human-machine safety; Optimal design

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1. Introduction

Toys are essential tools in the process of a child's growth. Toys on the market today are more complex, and the use types and product-based endeavors are diverse. Toys play an important role in children's growth. They help children learn about their surroundings and integrate into the society as they grow, which has a significant enlightening effect. With the continuous development and progress of science and technology, children's toys are becoming more and more intelligent, but there are still various types of hidden dangers in these toys that can affect children's physical and mental health [1-6]. For example, if toxic substances are used in the selection of production materials and are used by children over time, there will be an effect on their bodies. The implementation of the "Made in China 2025" plan clearly stipulated the improvement of manufacturing to a high-quality level and the achievement of a high market demand and high supply goal. At the same time, as the pillar of the future, it is the common responsibility of the state and all people to protect children's physical and mental health. Therefore, when manufacturing children's toys, green and high-quality production materials should be used. On the basis of ensuring the safety and quality level of children's toys, it is important to further improve the innovative design ability of children's toys and strengthen the craftsman spirit of the manufacturing industry. This puts forward higher requirements for manufacturers and designers [2-8]. Children's toys have certain hidden dangers. Strengthening the design and safety performance of children's toys as well as realizing human-machine safety interaction will not only engender a happy childhood and give full play to the educational role of toys in their growth stage, but also prevent injuries caused by toys. Taking the human-machine safety design of children's toys as the starting point, this study focuses on changing the product performance and design method, so as to provide children with high-quality and safe toys.

2. Types of toys and safety testing standards

2.1. Types of toys

Children's toys are not only articles that bring happiness to children. At present, toys are also widely used

in education to guide children to learn. From the perspective of education, toys can be divided into six categories: cognitive toys, language toys, science toys, action toys, operation toys, and social toys [8-13]. **Table 1** describes the types of toys in detail.

Table 1. Types of toys for children

Category	Effect	Type
Cognitive toys	Toys that can help children learn and establish various basic concepts, such as paired toys with shape, color, and relationship as clues, toys with game rules, and so on.	Jigsaw puzzle, stacking cups, etc.
Language toys	Toys that help develop children's hearing and promote language expression, organizational ability, as well as practice before writing.	Story tapes, story cards, drawing boards for painting, etc.
Science toys	Toys that can attract children to observe, compare, collect, and analyze. In addition to arousing their enthusiastic curiosity, children may form the habit of observing, analyzing, collecting data, doing things, and seeking truth from facts through these toys.	Microscope, kaleidoscope, various specimens, etc.
Action toys	Toys that can be used to train the coordination of muscles and various parts of the body.	Baby-crawling toys, all kinds of carts, bicycle-riding, dart-throwing, etc.
Action toys	Toys that can promote flexibility of finger muscles and coordination between eyes and hands.	Clay, threading, beading, stacking blocks, etc.
Social toys	Toys that enable children to express their emotions and experience people as well as the world outside. Children have more opportunities to understand their surroundings and absorb relevant life experience through these toys.	Dolls, stuffed toys, etc.; toys designed for life situations, such as supermarkets and airports.

In addition to considering the educational nature of toys, parents will naturally consider the safety of toys, and whether the toys will cause harm to their children. For example, a child's live can be threatened by accidentally swallowing parts that have fallen off from a toy. Aside from that, a damaged toy may be sharp, causing harm to the child. In order to avoid these situations, it is necessary to strengthen the safety detection of toys.

2.2. Safety testing standards for mechanical toys

The safety testing of toys is generally to test the physical properties of toys. Physical properties are the contents and factors that mainly affect the safety of toys for children. In order to reduce the risk of toys causing harm to children, it is necessary to test the physical properties of toys before they are sold. Toys that fail to pass the performance test need to be returned to the factory for reconstruction or destruction. The performance test of toys mainly includes tension test, torque test, bite force test, and so on.

(1) The bite force test is used to test the condition of a toy under the action of a normal bite force in consideration that the toy will be bitten by children, resulting in swallowing. When testing the bite force, a pulling force in pounds is mainly used for testing. At present, the test is carried out in accordance to the United States' test standard, as shown in **Table 2**.

Table 2. Bite force test standard

Age	Pounds
0-18 months	25 lbs
18-36 months	50 lbs
36-96 months	100 lbs

(2) The tension test is also measured by weight. The tension test is different from country to country. The specific standards are shown in **Table 3**.

Table 3. Tension test of toys in various countries

Age (month)	U.S.A	Europe	Thailand	China	Japan	Canada	Australia
0-18	46.7 N	If accessible size ≤	50 N	If accessible size		4.5 kg	5.2 kg
18-36	69.0 N	6 mm = 50 N	75 N	≤ 6 mm = 5.1 kg		4.5 kg	7.7 kg
36-96	69.0 N	If accessible size >	90 N	If accessible size		4.5 kg	9.3 kg
		6 mm = 90 N		> 6mm = 9.2kg			

3. Analyzing the causes of injury from toys

3.1. Hazards caused by artificial intelligence

There are many kinds of artificial intelligence products. With the integration of artificial intelligence into children's toys, the product form and use mode are more intelligent. Manufacturers and designers place a high value on the profitability [14,15] and intelligence of toys when designing and producing them, but the negative impact of artificial intelligence in these toys, as well as the safety issues brought about by artificial intelligence itself, are ignored, increasing the risk of harm to children's growth.

3.2. Hazards caused by cost and inferior materials

With the continuous expansion of international trade frictions and the sharp increase of resource consumption, the price of producing materials for children's toys is rising, resulting in an increase in the manufacturing cost. Under the condition of limiting the pricing of children's toys, the space for profit is gradually reducing. In order to enhance the interests of enterprises, manufacturers are suspected of cutting corners and using inferior products in the production of toys. As a result, the harmfulness of children's toys due to the use of inferior materials is increasing, and the toys produced do not meet the requirements of international export standards, resulting in safety issues.

3.3. Hazards caused by inappropriate mechanical structure

Due to the deficiencies of some production enterprises in production capacity and equipment, there are deficiencies in the details of the mechanical structure of toys, along with unreasonable structural design and flawed production technology, thus affecting the quality of toys and the safety of children. At the same time, in regard to the selection of toys, parents should consider their children's individual needs and select appropriate toys for them. For example, for children under the age of three, parents should select smaller and lighter toys to avoid accidents. Children of this age are too frail to hold heavy and bulky toys, and as a result, they may end up hitting themselves, thus causing physical injuries. Therefore, this is one of the most important aspects that parents should look into.

3.4. Hazards caused by flawed testing standards

At present, the current testing standards for children's toys in China are flawed. Only the mandatory safety

risks are specified in the standards for testing the safety of children's toys; there are no clear provisions on the subject other than the mandatory safety standards, resulting in the lack of judgement when testing unexpected safety issues and potentially leading to them.

4. Human-machine safety design optimization strategy for children's mechanical toys

4.1. Environmental-friendly design

Children's awareness of society is still insufficient as is their ability to avoid harm. Therefore, considering these characteristics, it is important to consider the harm to children when designing children's toys. When selecting design materials, those that are environmental-friendly and do not cause physical harm to children should be selected. In addition to ensuring that the toys are resistant to wear and wrestling, we it is also important to ensure that they are environmental-friendly. Materials that are less polluting, non-toxic, and recyclable should be prioritized in material selection [16-19], so as to achieve the goal of human-machine safety design and eliminate the risk of harm to children caused by these materials.

4.2. Structural optimization

In addition to children's interest, the safety of toys must also be considered. When designing toys, it is necessary to ensure the safety performance and firmness of toys. For instance, in the case of plastic toys, we should not only simplify the structure of toys, but also avoid certain designs, such as holes and eyes, on these toys. Children's toys must meet stringent structural requirements. These toys should also be ensured that they are fall resistant. It is crucial to ensure that the plastic shell does not disintegrate, and the toy parts do not break off after sustaining a fall, leading to accidental consumption by children. When optimizing the structural design of toys, designers and manufacturers should avoid shaping the external structure of toys with sharp corners to ensure the stability of parts. At the same time, the toy parts should be specially reinforced to avoid life-threatening hazards as a result of the fallen parts being consumed by children.

4.3. Shape optimization

Each child has different needs at different stages and different attraction for different toys. Toys of different shapes may harm children in various ways. For example, non-bulbous toys are nearly 30% more harmful to children than bulbous toys, but there are many non-bulbous toys on the market. When designing toys based on age groups, designers and manufacturers must design different types of toys for different age groups. In the selection of toys, parents should choose toys that conform to their children's age group with high safety features for their children to play with. The shape and structure of toys are very appealing to children. Therefore, it is very important to optimize the shape of toys.

4.4. Emotional interaction

"Made in China 2025" has put forward new requirements for the manufacturing industry, clearly stipulating that it is necessary to improve the quality of products while meeting the social needs of products, which implies that toy manufacturers and designers should innovate the design concept and discard the traditional one. While pursuing their own interests, manufacturers and designers also need to consider the design form and pay more attention to the physical and mental health of children to design better toys from the perspective of children's growth [20, 21].

For example, in designing the shape, it is best to focus on creating a rounded overall impression. On the whole, the structure is simple and has strong integrity, which reduces the use of parts, prevents parts from falling off and being consumed by children by accident, as well as reflects the characteristics of a sun in its overall form to attract their attention. Functional changes should be based on meeting the physical and mental health needs of children, giving full play to the role of toys in their growth as well as the function

of toys to inspire their intelligence and improve their hands-on skills. In the design, it is necessary to avoid designing toys that seem like food or having food smell, so as to prevent children from mistaking toys as real food and eating them by mistake. The improvement of the emotional interaction function of toys is primarily intended to enrich children's childhood, create a good living and learning environment for children, as well as teach children through play.

5. Conclusion

In a nutshell, the hazards of mechanical toys affecting children's safety include those caused by artificial intelligence, cost, inferior materials, inappropriate mechanical structure, and flawed testing standards. In order to avoid these hazards and strengthen the human-machine safety design of children's toys, it is necessary to optimize the design material and mechanism from the perspective of environmental protection, structure, and human-machine interaction, so as to ensure the safe use of toys among children.

Disclosure statement

The author declares no conflict of interest.

References

[1] Zhang T, 2022, Guide to the Annual Update of EU Toy Standards. Chinese and Foreign Toy Manufacturing, 2022(02): 68-70.

[2] Wu E, Wang Q, Dai S, et al., 2022, Quality and Safety Risk Analysis and Standard Status of Baby Dental Gel Products. China Standardization, 2022(01): 176-181.

[3] Fu D, Huang K, Tan Y, et al., 2021, Study on the Quality and Safety Risk of Inflatable Toys. Standard Science, 2021(11): 95-99.

[4] Lin P, Zhang H, Wang C, et al., 2021, Research on the Difference between toy Impact Test Method and Domestic and Foreign Testing Standards. Light Industry Standards and Quality, 2021(05): 47-49, 58.

[5] Xie J, Ye M, Wang R, et al., 2021, Quality and Safety Risk Analysis of Recalled Chinese Toys in Europe and America in 2019-2020. China Standardization, 2021(15): 208-213.

[6] Liao H, 2021, Ensure the Implementation of Quality and Safety Standards for Children's Products in Place, China Market Regulatory Journal, 007.

[7] Chen W, Liu B, 2021, Common Sense of Safety of Toys and Buggies. Fujian Quality and Technical Supervision, 2021(06): 43-44.

[8] Lin L, 2021, Quality and Safety Analysis of Magnet Toys. Toy Industry, 2021(06): 66-67.

[9] 2021, Promulgation of the Implementation Rules of Toy Quality Spot Check. Toy Industry, 2021(06): 67.

[10] Li Y, 2021, "Toylike stationery" May be a Safety Hazard. China Quality Promotion, 2021(06): 7-8.

[11] Zhou X, 2021, Pay Attention to the Quality of Strollers to Build a "Safety Fortress". Fujian Quality and Technical Supervision, 2021(04): 49.

[12] Wen F, 2021, Research on the Present Situation and Future Development Trend of Eu Toy Product Technical Legislation. Standard Science, 2021(02): 41-48.

[13] Wang P, 2021, Implementation of Quality Control in Toy Laboratory. Science, Technology and Innovation, 2021(01): 116-117.

[14] Qiao F, 2020, Quality and Safety Risk Analysis of Children's Toys. Standard Science, 2020(12): 167-170, 179.

[15] Huang G, Li S, 2020, Analysis of Safety Standard of Toy Gun. Chinese and Foreign Toy Manufacturing, 2020(12): 18-19.

[16] 2020, Update Industry Guide on Toy Safety Requirements. Toy Industry, 2020(12): 79.

[17] Xie L, Xu W, 2020, Research on Material Selection in Children's Toy Design. Yihai, 2020(08): 120-121.

[18] Zhang D, Zhang X, Yang X, et al., 2018, Design of Remote Control Toy Car for Children's Traffic Safety Awareness Training. Machinery Manufacturing and Automation, 47(04): 176-178, 211.

[19] Li X, 2017, Discussion on Toy Testing and Design Safety. Light Industry Standards and Quality, 2017(03): 58-59.

[20] Shi K, Liu M, 2013, Thoughts on Safety in Children's Toy Design. Popular Literature and Art, 2013(13): 69.

[21] Hu X, Li H, 2012, Man-Machine Safety Design of Children's Toys. Ergonomics, 18(04): 92-95.

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Journal article (print) with more than three authors

[2] Gamelin F.X., Baquet G., Berthoin S., et al. Effect of high intensity intermittent training on heart rate variability in prepubescent children. European Journal of Applied Physiology, 2009, 105: 731–738.

Journal article (online) with one to three authors

[3] Jackson D., Firtko A., Edenborough M. Personal resilience as a strategy for surviving and thriving in the face of workplace adversity: a literature review. Journal of Advanced Nursing, 2009, 60(1): 1–9,

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[4] Hargreave M., Jensen A., Nielsen T.S.S., et al. Maternal use of fertility drugs and risk of cancer in children—A nationwide population-based cohort study in Denmark. International Journal of Cancer, 2015, 136(8): 1931–1939.

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[5] Schneider Z., Whitehead D., Elliott D. Nursing and midwifery research: methods and appraisal for evidence-based practice. 3rd edn. 2009, Elsevier Australia, Marrickville, NSW.

Book with more than three authors

[6] Davis M., Charles L., Curry M.J., et al. Challenging spatial norms. 2013, Routledge, London.

Chapter or Article in Book

[7] Knowles M.S. Independent study. In Using learning contracts. 1986, Jossey-Bass, San Francisco, 89–96.

Others

Proceedings of meetings and symposiums, conference papers

[8] Chang S.S., Liaw L. and Ruppenhofer J. (eds). Proceedings of the twenty-fifth annual meeting of the Berkeley Linguistics Society, February 12–15, 1999: general session and parasession on loan word phenomena. 2000, Berkeley Linguistics Society, Berkeley.

Conference proceedings (from electronic database)

[9] Bukowski R.M. Prognostic factors for survival in metastatic renal cell carcinoma: update 2008. Innovations and challenges in renal cancer: proceedings of the third Cambridge conference. Cancer, 2009, 115 (10): 2273, viewed 19 May 2009, Academic OneFile database.

Online Document with author names

[10] Este J., Warren C., Connor L., et al. Life in the clickstream: the future of journalism, Media Entertainment and Arts Alliance, 2008. viewed 27 May 2009, http://www.alliance.org.au/documents/foj_report_final.pdf

Online Document without author name

[11] Developing an argument n.d., viewed March 30 2009, http://web.princeton.edu/sites/writing

/Writing_Center/WCWritingResources.htm

Thesis/Dissertation

[12] Gale L. The relationship between leadership and employee empowerment for successful total quality management. 2000, University of Western Sydney.

Standard

[13] Standards Australia Online. Glass in buildings: selection and installation. AS 1288–2006. 2006, SAI Global database.

Government Report

[14] National Commission of Audit. Report to the Commonwealth Government, Australian Government Publishing Service, 1996, Canberra.

Government report (online)

[15] Department of Health and Ageing. Ageing and aged care in Australia, 2008, viewed 10 November 2008, http://www.health.gov.au/internet/main/publishing.nsf/Content/ageing

No author

[16] Guide to agricultural meteorological practices. 2nd edn, Secretariat of the World Meteorological Organization, 2010, Geneva.

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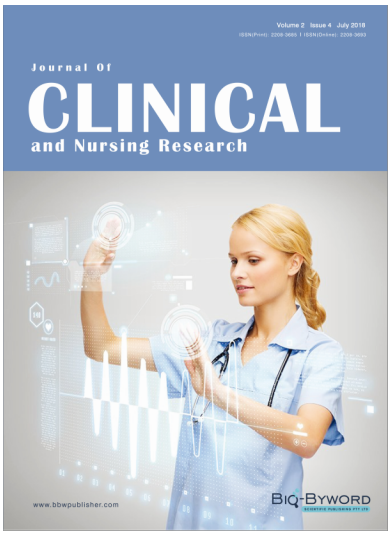

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