ingegneria sismica
International Journal of Earthquake Engineering
Anno XLIII - Num. 1 - 2026

Enhancement of Visual Effects of π - Conjugated Materials in Martial Arts Performance Costumes

Wenbei Tu[1,*]

[1] Shandong University of Arts, Jinan 250300, Shandong, China

SUMMARY: *With the development of technology and materials science, existing materials used to enhance the visual effects of martial arts performance costumes are difficult to achieve more futuristic and innovative visual effects, and cannot fully meet the needs of modern martial arts performance costume design. Therefore, this article aimed to study the application of π - conjugated materials to enhance the visual effect of martial arts performance costumes, enhance the artistic appeal and ornamental value of performances. At first, π-conjugated materials which are used for promoting the visual effect of martial arts performance clothes were chosen and devised. Secondly, according to the chosen π - conjugated material, the work of optical simulation and layout optimization was carried out. After that, the flow of making things was employed for structure optimization, hence to guarantee the best possible vision effects. In the end, the materials which are used for promoting the visual effect of martial arts performance clothes have been carried out comparison and analysis. The results showed that in terms of visual comfort and satisfaction, the use of π - conjugated material polystyrene had the highest score for martial arts performance costumes, which was 20.41% and 15.4% higher than the average score of costumes using the other two materials, respectively; on the aspect of color and tone matching, experts of martial arts performance clothing who also utilized π-conjugated material polystyrene gave the top score, which is 10.26% higher than the average score of clothing that uses the other two materials. With regard to the degree of gloss, the martial arts performance clothing that is made of π-conjugated material polystyrene presented an average gloss increment of 17.91% and 33.9%, respectively, when compared with the clothing made of the other two materials. On the aspect of the texture, the texture of martial arts performance costumes which use π - conjugated material polystyrene has more superior quality and is more appropriate for use. To make summation, the utilization of π-conjugated materials on martial arts performance clothing is advantageous for strengthening visual effects, and possesses high feasibility.*

KEYWORDS: *Martial Arts Performance Costume; π - Conjugated Materials; Optical Simulation; Layout Optimization; Genetic Algorithm*

1 Introduction

Martial arts performance clothing must satisfy two technical requirements in the real use on stage. They are required to retain mobility in the process of fast motion, large-range limb stretching, repeated direction turning and sudden posture alteration, hence they at the same time must keep distinct visual identifiability under directional illumination, changeable

*172333950@qq.com
https://doi.org/10.65102/is2026344

Published: 30 April, 2026

observation angles, and dynamic performance surroundings. This twofold demand makes martial arts clothing different from static display clothes and from traditional clothes whose visual effect is mainly evaluated under steady watching situations. In stage performance, costume effect is gotten through the mutual action of moving body lines, the light that is reflected, color arrangement, and surface texture. Because of this cause, the clothing design inside this situation relies upon the matching performance of material characters, light reaction, body movement, and crowd feeling from watchers.

This issue has become more important with the expansion of research in costume production, wearable performance technology, interactive garments, digital costume studies, and wearability evaluation. Existing studies indicate that visual enhancement in stage clothing is closely related to material selection, surface design, and performer–garment interaction [1-6]. Surface appearance alone does not determine visual quality in performance use. The garment must also remain comfortable in repeated action, stable during use, and effective within the lighting system of the stage. Once visual enhancement is treated as a material-design issue, research attention moves from decorative accumulation to the regulation of surface response under working conditions.

The importance of this change is especially obvious in martial arts show, in which clothing appearance directly influences the manner that movements are observed by the public. When one carries out striking, turning, jumping, landing and defensive transitions, this garment has the function of helping to transmit force, rhythm and direction. Unsteady strong light, excessive rigidity, or bad contrast under slanting illumination can make dynamic outline unclear and reduce stage performance effect, hence materials with more manageable light characters can promote the clarity of movement display. Hence, this problem therefore relates to both the beauty expression and the use effect of performance.

Traditional vision improvement has mainly depended upon silk gloss, satin reflection, embroidered work, metallic yarn, sequin, and bead. These components can raise brightness and strengthen style, but therefore their impacts frequently greatly rely on illumination angle and strength. Certain researchers also additionally append local weight or rigidity, thus limiting the flexibility of the active regions. Therefore, surface ornamentation can promote visual abundance without providing steady control regarding the garment's optical reaction.

Recent work on smart textiles, wearable fibers, luminescent systems, conductive fabrics, nanomaterial-assisted fibers, and photonic color structures has opened a broader design space for performance garments [7-11]. This research direction shows that brightness, contrast and visual effect can be promoted via material structure and the interaction between light and material, hence providing a more controllable way when compared with traditional single decoration method.

At the same time, the introduction of advanced materials into costume research requires greater precision in material definition. In some discussions, broad categories such as smart polymers, luminescent systems, or optically active materials are introduced at a general level, whereas the reported evidence is often tied to a much narrower material condition. Once the material category is expanded beyond the scope of the actual experiment, the conclusion may appear stronger than the reported data support. A narrower definition improves technical clarity and keeps the argument aligned with the evidence. The present study follows this stricter approach. It focuses on a polystyrene-based surface coating as the material demonstrator applied to martial arts performance costumes. The central research question concerns whether a specifically designed polymer coating can produce better stage-oriented visual performance than conventional decorative materials.

This narrower scope setting enhances the research in a number of aspects. It causes the material discussion to maintain alignment with the reported figures, tables, and comparisons, and therefore it defines the analytical target in a more precise manner. Instead of putting forward a wide statement about optically active polymers, this current research puts its emphasis on a particular coating situation which has separate optical and surface-processing characteristics. This therefore also lets simulation, surface arrangement, and flow control become easier for people to discuss on a technical level.

A method which is based on coating has significance for clothing use because it directly functions on the boundary surface among incoming light, clothing shape and visual feeling. If we compare with rebuilding the textile system on the fiber or yarn level, coating processing therefore is more feasible for garment manufacture and scene application. It provides a method which is practical for researching how the distribution of coating, the processing of surface, and the optical response have influences on the visual performance, and it does not need to replace the structural base of the garment.

The other cause for this research work is the existing disparity between material model construction and visual assessment in current studies on martial arts clothing. The early researches have mainly investigated symbolic meaning, aesthetic manner, and cultural connotation, thus they provide less measurable data about how material intervention alters stage visibility. In comparison, the study about light-reacting textile materials and high-molecular compounds has laid relatively solid technical foundation, however, it is seldom discussed from the perspective of actual requirements of martial arts performance clothing.

This research connects the two through regarding the costume surface as a technical interface that can be processed and tested. Therefore, this work has three tasks to complete: explaining the optical principle of the chosen coating, making clear its surface distribution and processing route, and checking whether it is better than traditional decoration materials in visual assessment. This comparison has included audience score giving, expert evaluation, gloss reaction, and image analysis which is based on texture.

On the aspect of research method, this study has constructed a connected route that starts from optical modeling, then goes to simulation, then surface optimization, then coating preparation, and finally goes to evaluation. In the aspect of application, it offers comparative proof that a coating which is made from polymer can enhance stage-directed visual working effect without depending only on the newness of materials. Through the limiting of the scope to one fixed coating condition and one explicit comparison framework, this study makes the argument keep consistent with the evidence and hence makes the research findings easier to carry out interpretation.

2 Application of π - Conjugated Materials in Martial Arts Performance Costumes

π - conjugated materials have unique electronic structures and can exhibit rich optical properties, such as color tunability, fluorescence, etc. [16-17]. These special properties let π-conjugated materials possess wide application future in domains for example luminous devices, biology imaging, and laser. Besides, the optical characters of π-conjugated materials have close connection with their structure, hence their performance can be optimized through the adjustment of the structure [18, 19].

2.1 Material Selection and Design

For the sake of deep going exploration of the usage and combination of π-conjugated materials in the domain of martial arts performance clothing, the most important and primary key point lies on careful and ponderous material choosing and tactic layout. This article specially chooses the utilization of polystyrene in martial arts performance clothing, the final goal of which is to optimize and enlarge the visual effect and feeling that are produced by the chosen materials.

Once the specific π - conjugated material is determined, a thorough matching analysis of the optical properties of polystyrene material is carried out to ensure that polystyrene material can be better integrated into the design of martial arts performance costumes. The Fresnel equation reflects the reflection and refraction phenomena of light at the interface of two different media, and is suitable for solving the transmission coefficient and reflectivity [20, 21]. The Fresnel equation is used to calculate the transmittance and reflectance of polystyrene materials in the visible light region, expressed as follows:

$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2 \quad (1)$$

$$\mathrm{T} = 1 - \mathrm{R} \quad (2)$$

In the equation, R refers to reflectivity; T refers to transmittance; n_1 refers to air refractive index, approximately 1; n_2 refers to polystyrene conjugated material, which is approximately 1.5 in the visible light range.

To ensure the softness and resilience of polystyrene in martial arts performances, low molecular weight polystyrene with lower glass transition temperature is selected. In addition, the weight distribution function of polymers is used to characterize the flexibility of molecular chains.

$$\mathrm{P(R)} = \frac{\pi^2}{2\mathrm{Nl}^2} \cdot \mathrm{R}^2 \cdot \exp\left(-\frac{\pi^2}{2\mathrm{Nl}^2} \cdot \mathrm{R}^2\right) \quad (3)$$

P(R) refers to the weight distribution function of the molecular chain, reflecting the probability that the molecular chain is at different lengths R; N is the number of chain segments of the molecular chain; l is the average length of each chain segment.

Equation (3) describes the probability distribution of molecular chains occurring within different length ranges, and characterizes the flexibility and randomness of the chains using an exponential function of higher-order terms, thereby reducing the probability of long-chain molecules occurring.

Surface treatment technology is used to improve the optical properties of polystyrene, and the periodicity of the material surface microstructure is designed so that the periodic characteristic size of the microstructure conforms to the Bragg diffraction equation, achieving specific wavelength light scattering and achieving the goal of optical performance control [22]. The equation is as follows:

$$\mathrm{n} \cdot \lambda = 2\mathrm{d} \cdot \sin\theta \quad (4)$$

n refers to the number of diffraction times; λ refers to the wavelength of the incident light; d refers to the periodic characteristic size of the material surface microstructure; θ is the incident angle.

The finite element method is utilized for optical modeling of polystyrene materials. In the transmission of electromagnetic waves, Maxwell equations are used. The core of classical electromagnetic field theory is the Maxwell electromagnetic field equations [23, 24]. Each of its equations has been confirmed by a large amount of experimental data, and its mathematical logic is very rigorous and has been tested by long-term practice. Therefore, its correctness is unquestionable [25, 26].

Discrete spatial grids are used to transform equations into matrix equations, and numerical calculations are used to simulate the transmission, reflection, absorption, and other characteristics of light waves in media.

Among them, the description of electric field includes Gauss's law and Ampere's law.

(1) Gauss's law

$$\nabla \cdot \mathrm{D} = \rho \tag{5}$$

In the equation, ∇ refers to the potential shift vector, and ρ refers to the charge density.

(2) Ampere's law

$$\nabla \cdot \mathrm{H} = \mathrm{J} + \frac{\partial \mathrm{D}}{\partial \mathrm{t}} \tag{6}$$

The variable interpretation of Ampere's law is shown in Table 1.

Table 1: Variable interpretation of Ampere's law

Sequence	Variable	Meaning
1	H	Magnetic field strength
2	J	Current density
3	$\frac{\partial \mathrm{D}}{\partial \mathrm{t}}$	Time derivative of electric displacement vector

The description of magnetic fields includes Gauss's law (magnetic fields have no monopoles) and Faraday's law of electromagnetic induction.

(1) Gauss's law

$$\nabla \cdot \mathrm{B} = 0 \tag{7}$$

In the equation, B refers to the magnetic induction intensity.

(2) Faraday's law of electromagnetic induction

$$\nabla \cdot \mathrm{E} = -\frac{\partial \mathrm{B}}{\partial \mathrm{t}} \tag{8}$$

E refers to the electric field strength, and $\frac{\partial \mathrm{B}}{\partial \mathrm{t}}$ refers to the time derivative of the magnetic field. When the magnetic field intensity changes over time, a vortex electric field is generated in space. The generation of vortex electric field is due to the induction of electric field caused by changes in magnetic field.

By means of optical simulation and layout optimization, the π - conjugated material polystyrene exhibits the best visual effect under different lighting conditions.

2.2 Optical Simulation and Layout Optimization

Optical analog calculation is mainly on the foundation of optical equations to depict the travel process of light in π-conjugated material polystyrene. The Schrodinger Equation is utilized to depict the electronic structure of π - conjugated material polystyrene, which can be written as:

$$\widehat{\mathrm{H}}\Psi = \mathrm{e}\Psi \tag{9}$$

In the equation, $\hat{H}$ refers to the Hamiltonian operator, which includes the kinetic and potential energy terms of the system. Ψ refers to the wave function, which describes the state of electrons in the system, and e is the calculated energy value.

The optical transmission property of the polystyrene-made covering was studied on the foundation of Maxwell's electromagnetism theory. Under the formulation of frequency domain, the interaction between the incoming light and the coating is expressed by means of the coupled change of the electric field and the magnetic field. This method was utilized by us to carry out the evaluation of the field distribution and the corresponding reflection and transmission performance of the surface which has the coating. In this circumstance, angular frequency is what depicts the oscillation feature of the input wave, while magnetic permeability and permittivity are the things that decide the material's electromagnetic reaction.

On the basis of optical simulation, layout optimization is achieved by adjusting the distribution of π - conjugated material polystyrene on the costumes to maximize its response to light and achieve the best visual effect. On this basis, a multi-objective optimization method based on the least squares algorithm is proposed, which includes maximizing brightness and color saturation.

The π - conjugated material polystyrene on the surface of martial arts performance costumes is distributed as (C(x, y, t)), which is the material distribution at position (x, y) and time (t). The optimization objective function is expressed as:

$$\int \text{surface area}\, f\left(C(x,y,t), \frac{\partial(C(x,y,t)}{\partial x}, \frac{\partial(C(x,,t)}{\partial y}, \frac{\partial^2(C(x,y,)}{\partial x^2}, \frac{\partial^2(C(x,y,t)}{\partial y^2}, \dots\right) dA \tag{10}$$

f refers to a certain function regarding the distribution of materials and their spatial derivatives, and the selection of f is mainly based on specific optimization objectives and required performance characteristics. A refers to the integration range of the surface region.

Genetic algorithm is a population-based random search method that gradually optimizes the distribution of materials to adapt to changes in lighting conditions by simulating natural selection and genetic inheritance mechanisms during evolution. Therefore, genetic algorithm is used as the optimization algorithm for the distribution of π - conjugated material polystyrene (C(x, y, t)).

The specific layout optimization steps are shown in Figure 1.

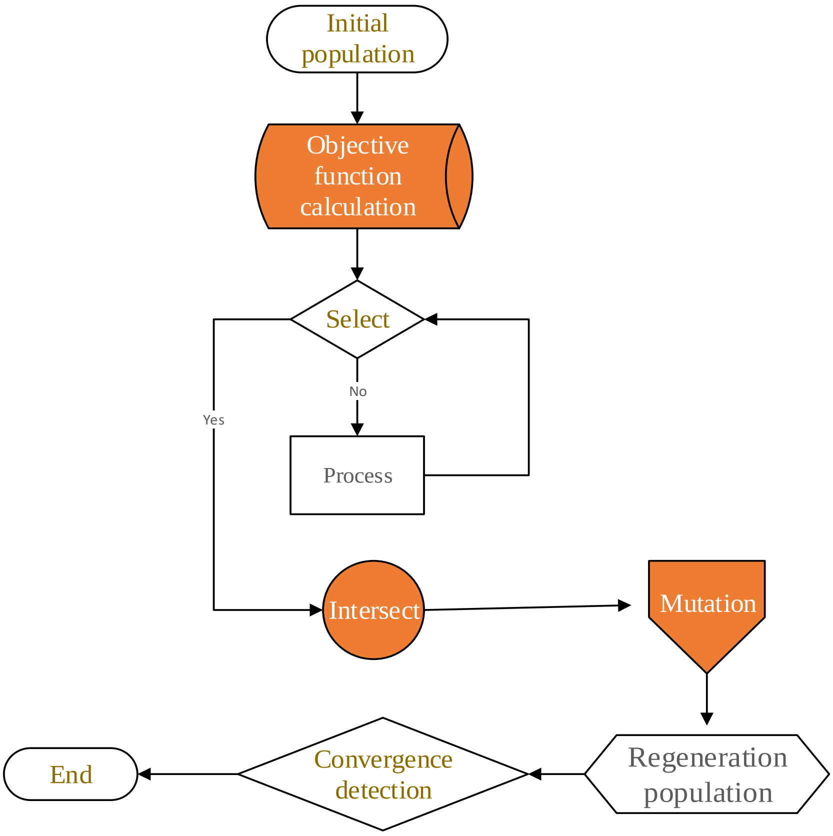

Figure 1: Layout optimization steps

Figure 1 shows the detailed steps to complete the entire layout optimization process:

Step 1: Initializing the group

A series of initial polystyrene distributions are randomly generated.

Step 2: Solving the objective function

Using the results of optical simulation, the objective function is solved.

Step 3: Selection

Based on the size of the objective function, the individual with the highest fitness is selected.

Step 4: Crossing

A new individual is generated through genetic crossover between selected individuals.

Step 5: Variation

Performing genetic variation on newly generated individuals brings randomness.

Step 6: Update population

Low adaptive individuals in the original population are replaced with newly generated individuals.

Step 7: Convergence detection

The optimal termination condition is detected: the convergence of the objective function or the maximum value of the iteration number.

2.3 Production Process and Structural Optimization

The preparation technology and structural optimization of π - conjugated material polystyrene for martial arts performance costumes are achieved through a series of complex and systematic technical means to ensure the optimal visual effect.

Firstly, in order to form a uniform and stable thin film of π - conjugated material polystyrene on the surface of costumes, this article adopts thin film coating technology. During the coating process, the thickness of the film is an important parameter that affects its performance, mainly depending on the wetting performance and coating speed of the coating.

The Young-Laplace equation is often used to describe the relationship between surface tension and pressure in liquid static equilibrium. Therefore, the Young-Laplace equation is used to describe the balance between liquid surface tension and pressure during the coating process:

$$\Delta P = \frac{\Gamma}{\Lambda} \tag{11}$$

In the equation, ΔP refers to the pressure difference of the liquid on the curved surface; Γ refers to surface tension; Λ refers to the curvature radius of the surface.

By using this equation, the pressure during the coating process can be flexibly adjusted to control the uniform deposition of π - conjugated material polystyrene, achieving a better coating effect.

After we guarantee even covering, surface handling technique is brought in to promote the binding intensity between π-conjugated material polystyrene and martial arts performance clothing base plate. The Young equation is utilized by people to depict the contact angle that lies between solid and liquid, and it considers the relation that exists between surface energy and interface energy. The equation is presented in the following:

$$\Omega = \Omega_S + \Omega_L + 2(\Omega_S \Omega_L)^{0.5} \cos\theta \tag{12}$$

Among them, Ω refers to the interfacial energy between solid and liquid; ΩS refers to the surface energy of a solid; ΩL refers to the surface energy of the liquid; $\cos\theta$ refers to the contact angle. This equation describes the energy relationship between solids and liquids, mainly used to analyze the effect of surface treatment techniques on the binding force of π - conjugated material polystyrene.

Surface treatment technology is utilized to alter the use of surfactants and the structure of surface treatment agents, enhancing the bonding strength between π - conjugated material polystyrene and martial arts performance costumes substrates. Enhanced adhesion can alter the contact angle $\cos\theta$ and affect the interfacial energy between solids and liquids Ω.

In the optimization design of the structure, the finite element method is used to simulate the stress state of the costumes. After considering the deformation and force distribution of costumes during the performance process, the mechanical properties of costumes materials are expressed using elastic mechanics equations.

The equation of elastic mechanics generally is utilized for describing the behaviors of solid materials that are under the effect of stress. Hooke's law, which belongs to the category of elasticity, is most fit to portray the relation between stress and strain of elastic materials:

$$S_\sigma = Y_m \cdot S_\varepsilon \tag{13}$$

Among them, S_σ refers to stress; Y_m refers to the Young's modulus, which is the stiffness coefficient; S_ε refers to strain. In finite element analysis, this equation is used to simulate the deformation and force distribution of polystyrene, a material used in martial arts performance costumes, under stress, in order to simulate and improve the stress situation of costumes.

Finally, by utilizing optical simulation to optimize the appearance of martial arts performance costumes, and using Fresnel and Young-Laplace equations, the reflection and refraction characteristics of π - conjugated materials under different lighting conditions are simulated. After completing the simulation, the surface microstructure and the hierarchical layout of π - conjugated materials are adjusted, and the optical properties are optimized, resulting in more eye-catching visual effects of martial arts performance costumes under different lighting conditions.

In summary, the optimization application of π - conjugated material polystyrene in martial arts performance costumes is mainly achieved through optimization of coating technology, enhancement of surface treatment, analysis of numerical simulation, and regulation of optical properties. These also provide in-depth and comprehensive technical support to enhance the artistic appeal and ornamental value of performance costumes.

3 Visual Effect Evaluation

The materials used for enhancing the visual effect of daily martial arts performance costumes include gorgeous materials such as silk, satin, gold thread, silver thread, as well as decorations such as embroidery, beads, and crystals. These materials and decorations can make costumes more gorgeous and eye-catching, enhance visual effects, and make performances more attractive.

In order to verify the visual effect of the π - conjugated material used in martial arts performance costumes in this article, a comparative analysis was conducted between martial arts performance costumes using silk and beads and martial arts performance costumes using conjugated material polystyrene. For the convenience of experimental recording, materials 1, 2, and 3 were used instead of the martial arts performance costumes made of silk, beads, and polystyrene.

Visual effect evaluation indicators include:

1) Visual comfort and satisfaction survey: Through a questionnaire survey, participants' subjective feelings and preferences for visual effects are understood.

2) Color and tone coordination: The combination of colors and tones in martial arts performance costumes using different materials is evaluated through expert evaluation.

3) Glossiness: The direct measurement method is used to measure the glossiness values in five aspects.

4) Texture: Image processing and computer vision techniques are adopted to extract texture features from martial arts performance costumes images.

3.1 Visual Comfort and Satisfaction Survey

Forty audience members who frequently watched martial arts performances were randomly selected as the experimental subjects for a visual comfort and satisfaction survey. They were asked to rate the visual comfort and satisfaction brought by the application of three different materials in martial arts performance costumes, with a maximum score of 5. The scoring results are shown in Figure 2.

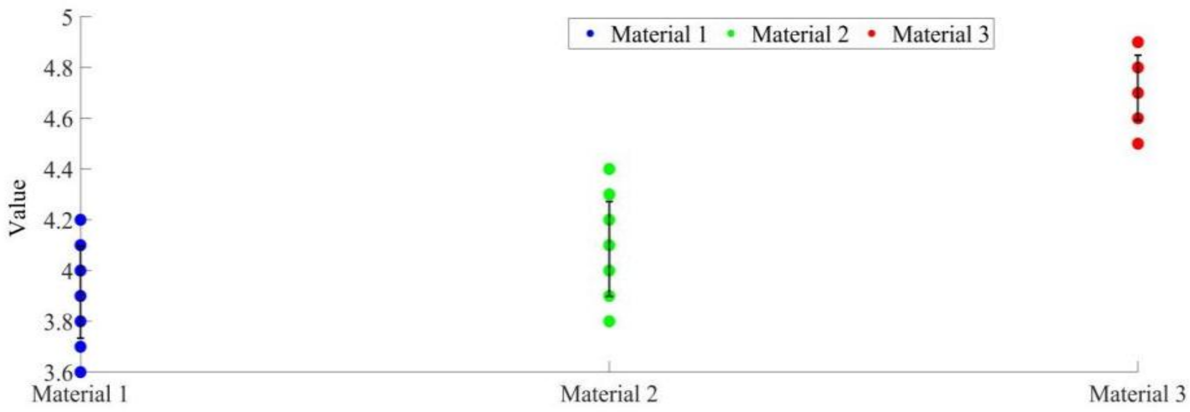

Figure 2: Visual comfort and satisfaction ratings of different materials applied in costumes (in points)

Figure 2 compares the visual comfort and satisfaction of three different materials applied in martial arts performance costumes. Scatter plot is the most common data analysis method, which can represent data points as a straight line and mark a value on each point. The comfort and satisfaction rating data for Materials 1, 2, and 3 were presented in the form of scatter plots, and error bars were added at the average value of each material to reflect the degree of variation in the rating data.

The horizontal axis represents costumes made of three different materials, while the vertical axis represents ratings for visual comfort and satisfaction.

The specific data in Figure 2 is:

The comfort and satisfaction grade data concerning Material 1 are what follow: 3.7, 3.9, 4.0, 3.8, 4.1, 3.6, 3.9, 4.2, 4.0, 3.8, 4.1, 3.7, 3.9, 4.0, 3.8, 4.1, 3.6, 3.9, 4.2, 4.0, 3.7, 3.9, 4.0, 3.8, 4.1, 3.6, 3.9, 4.2, 4.0, 3.8, 4.1, 3.7, 3.9, 4.0, 3.8, 4.1, 3.6, 3.9, 4.2, 4.0. The comfort and satisfaction grade data with regard to Material 2 are as what follows: 4.2, 4.0, 4.1, 3.8, 4.3, 4.0, 4.1, 3.9, 4.2, 4.4, 4.1, 3.8, 4.3, 4.0, 4.1, 3.9, 4.2, 4.4, 4.1, 3.8, 4.2, 4.0, 4.1, 3.8, 4.3, 4.0, 4.1, 3.9, 4.2, 4.4, 4.1, 3.8, 4.3, 4.0, 4.1, 3.9, 4.2, 4.4, 4.1, 3.8. The comfort and satisfaction grading data for the Third Material were as what follows: 4.8, 4.6, 4.9, 4.7, 4.5, 4.7, 4.8, 4.6, 4.7, 4.9, 4.8, 4.6, 4.9, 4.7, 4.5, 4.7, 4.8, 4.6, 4.7, 4.9, 4.8, 4.6, 4.9, 4.7, 4.5, 4.7, 4.8, 4.6, 4.7, 4.9, 4.8, 4.6, 4.9, 4.7, 4.5, 4.7, 4.8, 4.6, 4.7, 4.9.

The scoring data of martial arts performance costumes using three materials were presented in scattered dots of different colors. By displaying the mean and error bars, it can be seen that the average comfort and satisfaction ratings for each material of costumes were applied, and the degree of variation in ratings can be observed.

The score of Material 1 was generally distributed between 3.6 and 4.2; the score of Material 2 was generally distributed between 3.8 and 4.4; the score for Material 3 was generally distributed between 4.5 and 4.9. It was obvious that Material 3 had a higher score (red scatter) compared to the other two materials (blue and green scatter).

This means that in this field, π - conjugated material polystyrene has greater potential to enhance the visual effect of martial arts performance costumes. The difference in error bars also indicates that the rating of Material 3 is more stable.

Based on the rating data in Figure 2, a box plot was used to calculate the visual comfort and satisfaction scores of each material applied in martial arts performance costumes. The result is shown in Figure 3.

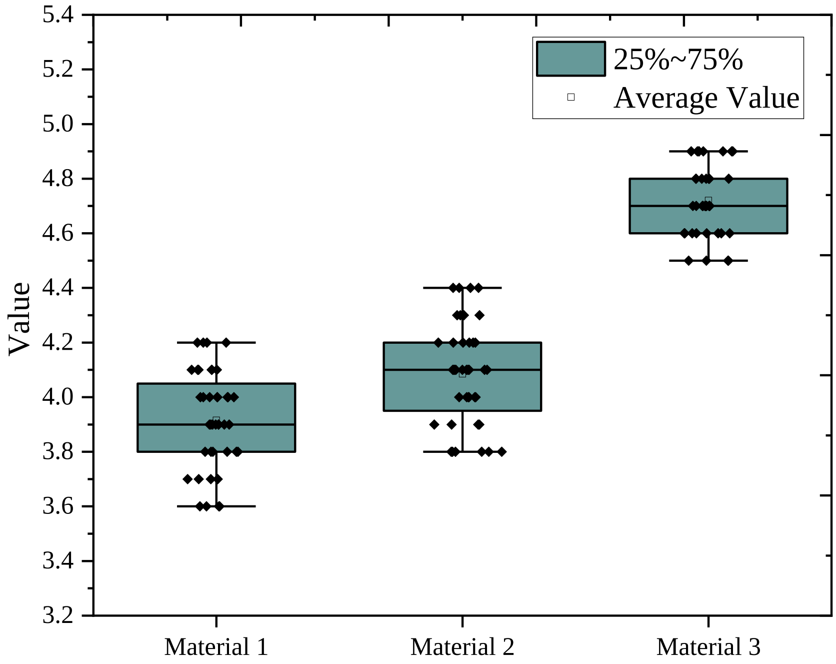

Figure 3: Average scores of visual comfort and satisfaction for the application of different materials in costumes (unit: points)

Figure 3 shows the average scores of visual comfort and satisfaction for the application of three different materials in martial arts performance costumes. Among them, the average score for Material 1 was 3.92; the average score for Material 2 was 4.09; the average score for Material 3 was 4.72.

The visual comfort and satisfaction score of Material 3 was 20.41% higher than that of Material 1, and 15.4% higher than that of Material 2.

The above data indicates that in practical applications, using π - conjugated material polystyrene can provide a more stable high-level visual effect without significant fluctuations.

3.2 Color and Tone Coordination

The coordination between colors and tones can affect the overall visual effect. A good color combination can enhance the beauty of martial arts performance costumes, highlight martial arts movements and postures, and convey the atmosphere and emotions of martial arts performances.

Five indexes that are used for appraising the color and tone harmony of martial arts performance clothes are: color contrast (A), skin color matching (B), color saturation (C), color matching (D), and color temperament (E).

Radar pictures were utilized to carry out comparison on the color and tone matching degree of three kinds of materials which are applied in martial arts performance clothing. Radar pictures can supply a visual compare of the coordination indexes of different colors and tones on martial arts performance clothes which are produced from three kinds of materials. The color and tone harmony marking points for diverse materials are displayed by Figure 4.

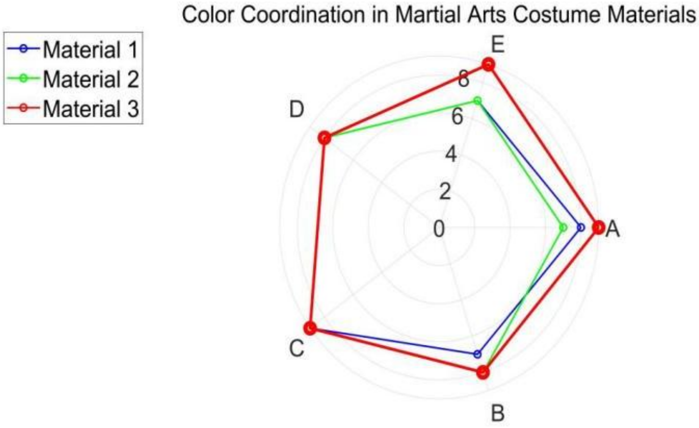

Figure 4: Color and tone coordination scores of different materials applied in martial arts performance costumes (unit: points)

In Figure 4, the horizontal axis stands for different evaluation indicators (A, B, C, D, E), every one of them stands for a specific aspect of the evaluation of the color and tone matching of martial arts performance costumes. The perpendicular axle stands for the marking that each material gets on each index, the scope of which is from 1 to 10. The more far you leave from the middle of the graph, the more high you will get the score.

The scores of Materials 1 and 2 on each evaluation indicator were relatively stable, with little variation, fluctuating between 7 and 9. Showing relatively consistent performance, but overall rating was not as stable and high as Material 3.

Material 3 maintained a higher score on all indicators, with most scoring 9, demonstrating relatively high performance in color and tone coordination. This represents that π - conjugated material polystyrene can provide stronger visual effects for martial arts performance costumes.

Similarly, according to the data in Figure 4, the color and tone coordination scores of each material applied in martial arts performance costumes were calculated, as shown in Table 2.

Table 2: Average score of color and tone coordination for each material applied in martial arts performance costumes (unit: points)

Category Score	A	B	C	D	E	Average value
Material 1	8	7	9	8	7	7.8
Material 2	7	8	9	8	7	7.8
Material 3	9	8	9	8	9	8.6

According to Table 2, it can be seen that the color and tone coordination of Materials 1 and 2 were evenly distributed, both of which were 7.8; Material 3 had the highest average score of 8.6 for color and tone coordination, which was 10.26% higher than the average score of Materials 1 and 2.

3.3 Glossiness

Martial arts performance costumes made of different materials have different reflective effects. Materials with higher glossiness can enhance the visual beauty of martial arts performance costumes.

Glossiness is an indicator used to measure the smoothness and reflectivity of the surface of the object being tested. When measuring the glossiness of martial arts performance costumes, the following five aspects need to be considered:

Reflectivity: It refers to the ability of the surface of martial arts performance costumes to reflect light, that is, how much it can reflect from the surface of martial arts performance costumes. High reflectivity indicates that martial arts performance costumes have a high gloss.

Smoothness: It refers to the smoothness of martial arts performance costumes. The higher the smoothness, the more concentrated the angle of reflection when light is reflected off the surface of the costumes, resulting in a stronger luster.

Transparency: It refers to the degree of transparency on the surface of martial arts performance costumes. Transparent costumes surfaces can display a different glossiness than other surfaces.

Uniformity: It refers to the reflection of light on the surface of martial arts performance costumes. A smooth costumes surface can reflect light evenly in any direction.

Clarity: It refers to the degree of precision of reflected light. Clear costumes reflective surfaces can exhibit better gloss effects.

The glossmeter is used to directly measure the intensity of light reflected on the surface of martial arts performance costumes. This device measures glossiness by reflecting light at a certain angle. During testing, factors such as reflection angle, test light source, and observation angle all affect the glossiness of the finished product.

Surface images are used to display the glossiness data of martial arts performance costumes in different aspects under three different materials. Through surface graphs, it is possible to visually compare the differences in glossiness among three different materials of martial arts performance costumes, and highlight the materials with better glossiness, as shown in Figure 5.

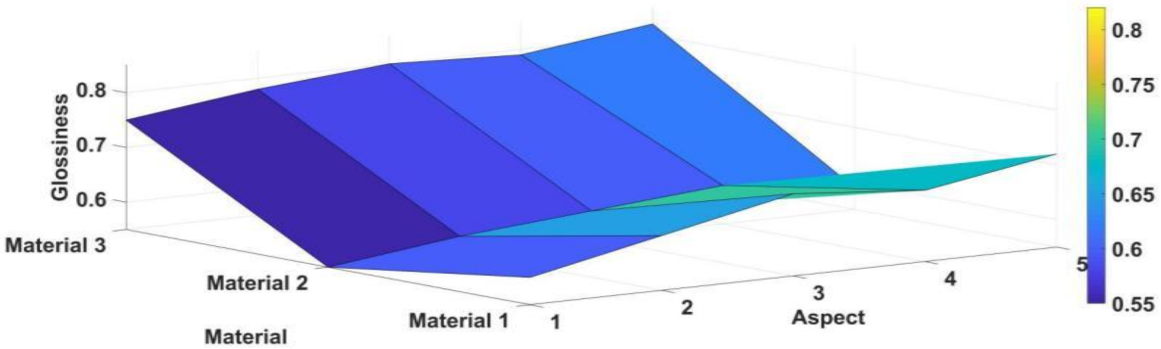

Figure 5: Glossiness of martial arts performance costumes made of different materials

In Figure 5, the X-axis reflects five different aspects of glossiness (where 1 represents reflectivity; 2 represents smoothness; 3 represents transparency; 4 represents uniformity; 5 represents clarity); the Y-axis represents three different materials of martial arts performance costumes; the Z-axis represents the value of glossiness.

The depth and color changes on the right side represent the glossiness values in different glossiness aspects. The values of Material 1 in different glossiness fluctuated roughly between 0.6 and 0.72; the glossiness value of Material 2 ranged from 0.55 to 0.62 in different aspects, and the variation was relatively small; Material 3 had a glossiness value between 0.75 and 0.82 in different aspects, indicating a higher overall value.

From this surface graph, it was evident that Material 3 had significantly higher values in all aspects of glossiness than Materials 1 and 2. The glossiness of Material 3 was more stable and the overall value was higher, indicating that in martial arts performance costumes, π -conjugated material polystyrene can provide better glossiness compared to the other two materials, which can enhance the visual effect of the costumes.

According to the glossiness values in Figure 5, the average glossiness of martial arts performance costumes made of different materials was calculated, as shown in Table 3.

Table 3: Mean glossiness of martial arts performance costumes made of different materials

Category Value	1	2	3	4	5	Average value
Material 1	0.6	0.65	0.7	0.68	0.72	0.67
Material 2	0.55	0.58	0.6	0.62	0.59	0.59
Material 3	0.75	0.78	0.8	0.79	0.82	0.79

Table 3 calculated the average glossiness of martial arts performance costumes made of different materials. Material 2 had the lowest average glossiness, followed by Material 1, and Material 3 had the highest average glossiness. The average glossiness of Material 3 was 17.91% and 33.9% higher than that of Materials 1 and 2, respectively.

3.4 Texture and Texture

Gabor filters were used to extract texture features of martial arts performance costumes from different materials. The texture characteristics of three different materials of martial arts performance costumes were compared, as shown in Figure 6.

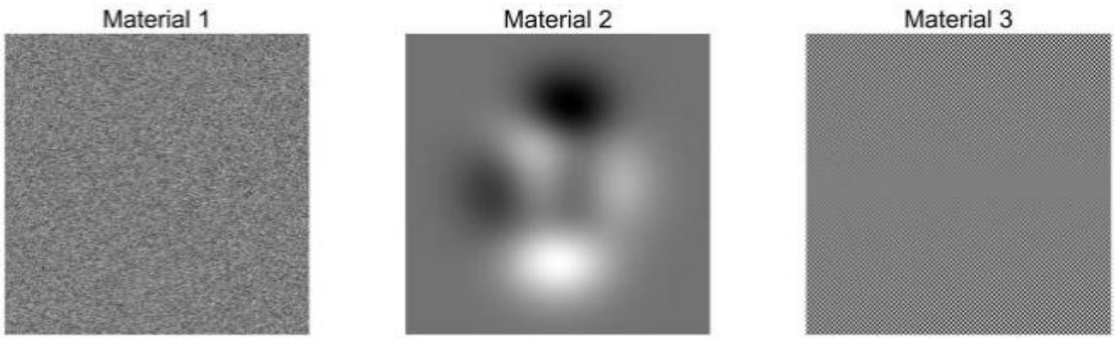

Figure 6: Texture and texture of martial arts performance costumes made of different materials

Figure 6 (texture visual image) provides an intuitive visual comparison, allowing for direct comparison of the texture of martial arts performance costumes made from different materials. Each subgraph represents different types of martial arts performance costumes (Material 1, Material 2, Material 3), displaying corresponding texture visual effects. Material 1 showed that the corresponding costumes presented random texture features; Material 2 showed that the corresponding costumes presented some structured and regular texture features; Material 3 showcased a more unique and eye-catching texture in the corresponding costumes.

Next, texture analysis was performed on Figure 6, as shown in Figure 7.

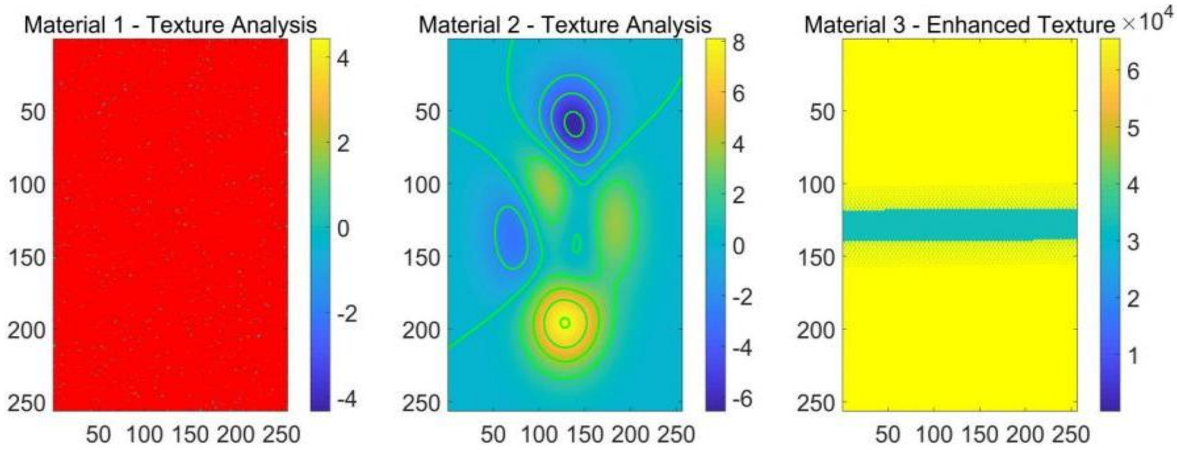

Figure 7: Texture analysis of martial arts performance costumes made of different materials

In Figure 7, the addition of contour lines highlights specific texture features of different materials. These features can help determine which material has more suitable texture characteristics, suitable for enhancing the visual effect of martial arts performance costumes.

The level and upright shafts stand for the coordinate values (x, y) of image picture elements. Inside this group, the first material adopts grayscale to show the picture, and the outline lines make certain texture characteristics or borders become outstanding by using red color. Material 2 utilizes different color matchings to stress particular texture characteristics in the image by means of green contour lines. The texture data of Material 3 is shown in color by means of the imagesc function. The yellow outline lines stress special texture characters or dividing lines, therefore pointing out their special texture characters which are compared with Material 1 and Material 2. These characteristics have very important meaning for the design of martial arts performance costumes, and therefore can promote the visual effect of costumes on the stage.

4 Conclusions

Martial art show is a comprehensive show activity which puts together body quality, techniques, and art. Wu shu performance clothes are the most key component of martial art performance activities. Because of their near connection between visual effects and motions, hence it is necessary to conduct research on new materials for the enhancement of visual effects. π - conjugated materials can change the visual display in accordance with the depth and category of color, hence enhancing the visual display. The research outcomes show that π - conjugated materials possess a remarkable visual promotion function in martial arts performance clothing. Its special electronic structure and light-related properties have given new thoughts and approaches for the design and manufacture of martial arts performance clothes. In the future, research work can further go on to investigate the potential application scopes of π-conjugated materials in other domains, for example stage illumination, film and television special effects, and so on.

About the Author

Wenbei Tu was born in Jinan, Shandong, P.R. China in 1979. She graduated successively from Beijing Film Academy and Central Academy of Drama, obtaining her Master's degree and Doctoral degree respectively. She is currently a faculty member of the School of Drama, Shandong University of Arts. Her main research fields include Drama, Film and Television Performance, and Directing Art Studies.
E-mail: 172333950@qq.com

References

[1] Porterfield, A., & Lamar, T. A. M. (2021). A framework for incorporating virtual fitting into the costume design and production process. International Journal of Fashion Design, Technology and Education, 14(1), 91-100.

[2] Hartman, K., Puckett, N., & Tindale, A. (2023). Designing wearable technology for opera. Proceedings of the 2023 ACM Designing Interactive Systems Conference, 1411-1423.

[3] Freire, R., & Reed, C. N. (2024). Body Lutherie: Co-designing a wearable for vocal performance with a changing body. Proceedings of the International Conference on New Interfaces for Musical Expression, 117-126.

[4] Zhang, K. (2025). Costume as interface: Wearable technology and the future of interactive storytelling in theatre. Journal of Cultural Analysis and Social Change, 10(2), 1820-1828.

[5] Su, Z. (2025). Immersive teaching model for traditional Chinese opera costume design based on virtual reality: digital cultural heritage, inheritance, and innovation. Scientific Reports, 15(1), 34830.

[6] Seo, Y. W., La Marca, V., Tandon, A., Chiao, J.-C., & Drummond, C. K. (2024). Exploring the design for wearability of wearable devices: A scoping review. Computers, 13(12), 326.

[7] Ding, Y., Jiang, J., Wu, Y., Zhang, Y., Zhou, J., Zhang, Y., Huang, Q., & Zheng, Z. (2024). Porous conductive textiles for wearable electronics. Chemical Reviews, 124(4), 1535-1648.

[8] Zhu, L., Zhang, W., Luan, S., Wei, J., Yang, Y., & Miao, J. (2025). Nanomaterials for smart wearable fibers and textiles: A critical review. iScience, 28(8), 113126.

[9] Xu, S., Fan, X., Chen, S., Manshaii, F., Yin, J., & Chen, J. (2024). Advances in luminescent fibers for interactive smart textiles. cMat, 1(3), e33.

[10] Cheng, J., Wang, Y., Cai, W., Xu, L., Li, J., & Zou, J. (2025). Color-changing smart textiles for zero-carbon radiative thermal management: A review. Applied Materials Today, 44, 102768.

[11] Pan, B., Gao, W., Li, Y., Jony, I. A., & Yang, S. (2025). Preparation and applications of photonic crystal structural color fibers. AATCC Journal of Research, 12(1), 1-18.

[12] Chougle, A., Rezk, A., Afzal, S. U. B., Mohammed, A. K., Shetty, D., & Nayfeh, A. (2025). Evolving role of conjugated polymers in nanoelectronics and photonics. Nano-Micro Letters, 17(1), 230.

[13] Jiang, H., Yang, C.-Y., Tu, D., Zhong, Y., Chen, Z., Huang, W., Feng, L.-W., Sun, H., Müller, C., Facchetti, A., Zhu, M., & Wang, G. (2025). Shear-enhanced liquid-crystal spinning of conjugated polymer fibers. National Science Review, 12(10), nwaf331.

[14] Giraud, L., Grelier, S., Grau, E., Hadziioannou, G., Brochon, C., & Cramail, H. (2020). Upgrading the chemistry of π-conjugated polymers toward more sustainable materials. Journal of Materials Chemistry C, 8(29), 9792-9810.

[15] MacFarlane, L. R., Shaikh, H., Garcia-Hernandez, J. D., Vespa, M., Fukui, T., & Manners, I. (2021). Functional nanoparticles through π-conjugated polymer self-assembly. Nature Reviews Materials, 6(1), 7-26.

[16] Hughes, T. W., Williamson, I. A. D., Minkov, M., & Fan, S. (2019). Forward-mode differentiation of Maxwell's equations. ACS Photonics, 6(11), 3010-3016.

[17] Liu, H., Rondi, L., & Xiao, J. (2019). Mosco convergence for H(curl) spaces, higher integrability for Maxwell's equations, and stability in direct and inverse electromagnetic scattering problems. Journal of the European Mathematical Society, 21(10), 2945-2993.

[18] Ern, A., & Guermond, J. L. (2018). Analysis of the edge finite element approximation of the Maxwell equations with low regularity solutions. Computers & Mathematics with Applications, 75(3), 918-932.

[19] Hermann, J., Schätzle, Z., & Noe, F. (2020). Deep-neural-network solution of the electronic Schrödinger equation. Nature Chemistry, 12(10), 891-897.

[20] Sohail, A. (2023). Genetic algorithms in the fields of artificial intelligence and data sciences. Annals of Data Science, 10(4), 1007-1018.

[21] Sun, Y., Xue, B., Zhang, M., Yen, G. G., & Lv, J. (2020). Automatically designing CNN architectures using the genetic algorithm for image classification. IEEE Transactions on Cybernetics, 50(9), 3840-3854.

[22] Behroozi, F. (2022). A fresh look at the Young-Laplace equation and its many applications in hydrostatics. The Physics Teacher, 60(5), 358-361.

[23] Mo, J., Sha, J., Li, D., Li, Z., & Chen, Y. (2019). Fluid release pressure for nanochannels: The Young-Laplace equation using the effective contact angle. Nanoscale, 11(17), 8408-8415.

[24] International Organization for Standardization. (2014). ISO 2813:2014. Paints and varnishes—Determination of gloss value at 20°, 60°, and 85°.

[25] ASTM International. (2025). ASTM D523. Standard test method for specular gloss.

[26] Commission Internationale de l'Eclairage. (2018). CIE 015:2018. Colorimetry (4th ed.).