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# Research on the construction of gene library of tie-dyeing technology based on AI-aided design

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## Summary

**Tie-dyeing is an important part of traditional Chinese culture and has profound historical heritage and artistic value. With the advancement of modern industrialization, traditional tie-dye techniques are facing the dilemma of inheritance, especially the depletion of dye resources, the lack of process innovation and the reduction of market demand. With the rapid development of artificial intelligence (AI) technology, especially breakthroughs in the fields of image generation, deep learning and data mining, AI technology has brought new opportunities for the protection, inheritance and innovation of tie-dye skills. In this paper, we propose a framework for the construction of a gene database of tie-dye technology based on AI-assisted design, combined with generative adversarial network (GAN), convolutional neural network (CNN) and other technologies, to explore how to establish a tie-dye pattern database, optimize the tie-dye process, preserve natural dye genes, and promote the digital protection and global promotion of tie-dye technology. Through the elaboration of the details of technical realization, the feasibility and practical path of AI in the innovation and inheritance of tie-dyeing skills are proposed.**

## Keywords

**AI intelligent design, tie-dyeing techniques, genetic library, intangible cultural heritage, digital protection, Intelligent optimization.**

## 1. Introduction

### 1.1. Background

As a form of traditional Chinese dyeing art [1] , tie-dyeing has a history of thousands of years. Its unique dyeing methods and pattern designs play an important role in folk customs, festivals, and religious ceremonies throughout China. Tie-dye uses the binding, kinking, and pressing of the cloth to make the dye penetrate into some parts of the cloth to form a pattern with strong local characteristics. Whether it's in ornaments, clothing, or household items, tie-dye patterns showcase a unique artistic appeal.

However, with the advancement of modern production, the traditional tie-dyeing technology is facing the impact of industrialization, but also exposes a number of problems: on the one hand, the natural dye resources are gradually depleted, resulting in the rising manufacturing cost of traditional dyes; On the other hand, the tie-dye process lacks innovation in the market, lacking the combination of technical heritage and modern design. As an important development direction of modern technology, AI technology is providing strong technical support for the innovation of tie-dye technology [2] , especially in generative design, process optimization, and dye resource protection.

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### 1.2. Research Objectives and Methods

The purpose of this study is to explore how AI-aided design can play a role in the construction of tie-dye gene database [3] , and to propose a framework for using AI technology to construct tie-dye pattern database, optimize process flow and protect dye genes. Specific objectives include:

1. Tie-dye pattern database construction: Digitize traditional tie-dye patterns through AI technology, and provide data support for subsequent design and innovation.

2. Tie-dyeing process optimization: AI is used to intelligently optimize the tie-dyeing process to improve production efficiency and ensure dyeing results.

3. Dye gene protection: Preserve and protect the genes of traditional natural dyes through AI technology to promote sustainable development [4] .

4. Market application analysis: study how to design tie-dye products that meet modern needs through AI technology and promote them to the market.

Research methods include literature analysis, case studies, and technical implementations. The literature analysis part reviews the application of AI technology in traditional crafts, combines the history and challenges of tie-dyeing technology [5] , and proposes the feasibility of technology application. The case study section will analyze the specific performance of AI in tie-dyeing skills with practical application examples. The technical implementation section details how AI can support tie-dye pattern generation, process optimization, and dye protection.

## 2. The framework for the construction of the gene library of tie-dye techniques

### 2.1. Tie-dye pattern database construction

#### 2.1.1. Data collection and digitization

The database construction of tie-dye patterns is one of the core contents of the gene library. In order to present and preserve the traditional tie-dye patterns in their entirety, the various patterns of the tie-dye process must be fully captured and digitized. The design style of tie-dye patterns varies according to factors such as region, ethnicity, and cultural background. For example, Yunnan's "Yunnan tie-dye" is known for its intricate geometry and colorful designs; The Yao tie-dye in Guangxi focuses on the layering of colors and the symbolism of patterns.

Each pattern is stored in a database in high-resolution images using high-definition photography or scanning equipment, and labeled in detail. Each pattern will include its color information, morphological characteristics, lines, symmetry, etc., and each pattern will be labeled with a unique label based on its historical and cultural background, so that AI can train and recognize it.

#### 2.1.2. AI-assisted pattern design

Using AI techniques, especially generative adversarial networks (GANs) and convolutional neural networks (CNNs), it is possible to generate new tie-dye patterns and even incorporate modern elements for innovative designs [6] . GAN generates a new pattern through the adversarial training of two neural networks, the generator is responsible for creating the pattern, and the discriminator is responsible for judging whether the pattern is in line with the tie-dye [7] style.

Here's the basic code implementation for GAN to generate tie-dye patterns:

```
import torch
import torch.nn as nn
import torch.optim as optim
from torch.autograd import Variable
```

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```
# Definition of Generator (Generate Tie-Dye Patterns)
class Generator(nn.Module):
    def __init__(self):
        super(Generator, self).__init__()
        self.fc = nn.Sequential(
            nn.Linear(100, 256),
            nn.ReLU(),
            nn.Linear(256, 512),
            nn.ReLU(),
            nn.Linear(512, 1024),
            nn.ReLU(),
            nn.Linear(1024, 3 * 64 * 64),
            nn.Tanh()
        )

    def forward(self, z):
        return self.fc(z).view(-1, 3, 64, 64)

# Definition of Discriminator (Determining the Authenticity of the Pattern)
class Discriminator(nn.Module):
    def __init__(self):
        super(Discriminator, self).__init__()
        self.fc = nn.Sequential(
            nn.Linear(3 * 64 * 64, 1024),
            nn.LeakyReLU(0.2),
            nn.Linear(1024, 512),
            nn.LeakyReLU(0.2),
            nn.Linear(512, 1),
            nn.Sigmoid()
        )

    def forward(self, x):
        return self.fc(x.view(-1, 3 * 64 * 64))

# Initialize generator and discriminator
generator = Generator()
discriminator = Discriminator()

# Random noise input
z = torch.randn(1, 100)

# Generate an image
generated_image = generator(z)
```

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In this way, AI can continuously generate new and tie-dye-inspired patterns, breathing modern life into traditional art. Such technologies not only provide creative support, but also provide inspiration for designers [8].

## 2.2. Tie-dyeing process database construction

Tie-dye is not only a presentation of visual art, but also involves multiple processes such as dyeing, binding, and knotting. The application of AI technology in process optimization can greatly improve production efficiency, ensure process quality, and optimize the use of [9] dyes.

### 2.2.1. Digitalization of the process

Every step of the tie-dye process should be digitized and standardized, including fabric selection, bundling techniques, dye ratio, dyeing time, dyeing temperature, etc. Digitalization not only enables each link to be recorded in detail, but also provides sufficient data support for subsequent AI optimization.

Using 3D modeling and simulation technology, virtual models can be created for each process step, simulating every detail of the dyeing process for process optimization. For example, virtual reality (VR) technology can be used to demonstrate the tie-dye process, enabling operators to train and learn on a digital platform.

### 2.2.2. AI intelligent optimization

AI technology can automatically optimize every step of the tie-dye process by analyzing large amounts of historical data. For example, through the machine learning model, the influence of different dye ratios and different bundling methods on the dyeing effect can be analyzed, and the optimal combination of process parameters can be automatically generated [10] .

Taking the random forest regression model as an example, it can analyze the relationship between multiple input variables (such as dye concentration, temperature, time, etc.) and output results (such as staining effect) to generate an optimal staining protocol.

```
from sklearn.ensemble import RandomForestRegressor

# Sample data: the effects of dye concentration, temperature, and time on the dyeing effect
X = [[10, 30, 15], [20, 40, 20], [15, 35, 18], [25, 50, 25]]
y = [0.7, 0.9, 0.8, 1.0] # Staining effect score

# Train a random forest model
model = RandomForestRegressor(n_estimators=100)
model.fit(X, y)

# Predict the staining effect of new samples
new_data = [[18, 40, 22]]
predicted_effect = model.predict(new_data)
```

In this way, AI is able to automatically generate optimizations for the process, reducing manual intervention, increasing production efficiency and ensuring product quality.

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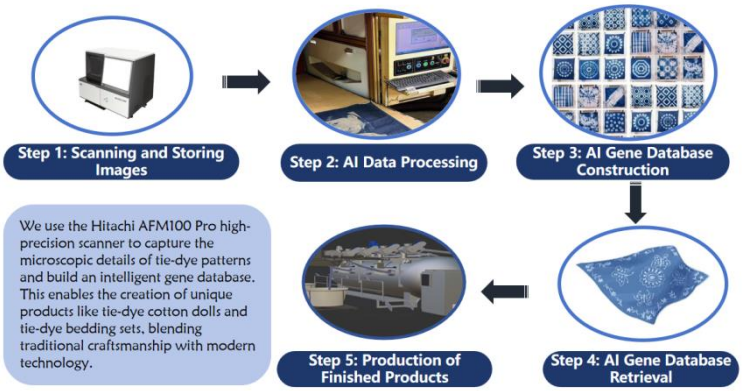


**Figure 1** Production flow chart

## 3. Conclusions and prospects

The construction of tie-dyeing technology gene library based on AI-assisted design provides a new solution for the protection, innovation and marketing of traditional crafts. Through measures such as digital pattern library, intelligent optimization of process flow and dye gene protection, tie-dye technology can be revitalized in the digital age. AI technology not only improves the production efficiency of tie-dye art, but also breaks through geographical restrictions and promotes its dissemination and application on a global scale.

In the future, with the further development of technology, AI will play an even more important role in tie-dyeing techniques. Through technologies such as deep learning and generative adversarial networks, the tie-dye process will continue to be innovated and improved, and sustainable development will be possible. In addition, AI technology will also play a vital role in the protection and inheritance of tie-dye culture, so that this traditional art can be better inherited and carried forward in modern society.

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