2024「中技社科技獎學金」

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研究獎學金

Research Scholarship

結合人工智慧與雷射著色技術之薄膜顏色預測模型

AI-driven Laser Coloring: A Predictive Model for Thin-Film Color Generation

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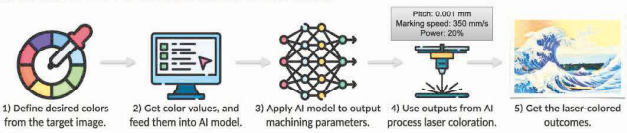
研究重點

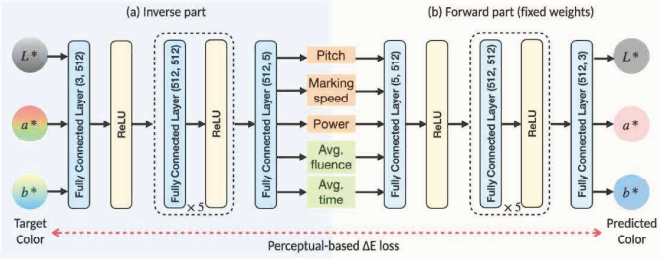
Laser-induced thin film coloration enables vibrant, durable, and eco-friendly color production, aligning with ESG principles and finding applications such ad aerospace and medical devices. However, the process involves complex, nonlinear interactions between laser parameters and colors, making traditional trial-and-error approaches inefficient. To address these challenges, we propose a physics-driven tandem neural network (PD-TNN) that incorporates critical physical properties—average fluence and average time—into the model. Additionally, we introduce a perceptual-based ΔE loss function, ensuring alignment with human visual perception. Using a dataset of over 2400 samples, PD-TNN achieves an average ΔE of 1.48, significantly outperforming baseline model. These results highlight the significance of integrating physical insights and using a perceptual evaluation metric as the loss, offering a precise and efficient solution for laser coloration.

研究動機與方法

- **Motivation for AI-driven laser coloration**



- **Architecture of PD-TNN for laser coloration**



- **Physical parameters in PD-TNN**

$$F = \frac{P}{V \times \Delta y} \qquad \tau = \frac{1}{V \times \Delta y}$$

F : Average fluence
τ : Average time
P : Power (%)
V : Marking speed (mm/s)
Δy : Pitch (mm)

- **Titanium samples with parameter values**

研究成果

- **Evaluation matrix: ΔE**

$$\Delta E = \sqrt{(L_t^* - L_p^*)^2 + (a_t^* - a_p^*)^2 + (b_t^* - b_p^*)^2}$$

F : Average fluence
τ : Average time
L_t^*, a_t^*, b_t^* : Lab* values of target color
L_p^*, a_p^*, b_p^* : Lab* values of model's prediction

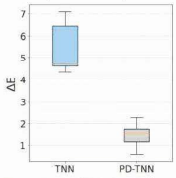
- **Ablation study for the forward model**

Loss	MP only	W/ F	W/ τ	W/ F & τ
MSE	5.42	5.33	5.10	4.89
ΔE	4.95	3.99	4.12	**3.81**

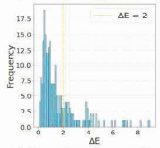
- **Ablation study for PD-TNN**

Loss	TNN	W/ F	W/ τ	PD-TNN
MSE	5.43	5.91	4.60	3.03
ΔE	3.55	4.21	3.51	**1.48**

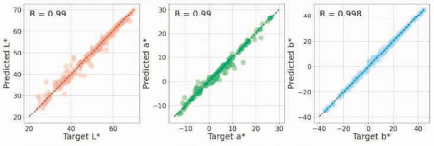
- **Box plot comparison**



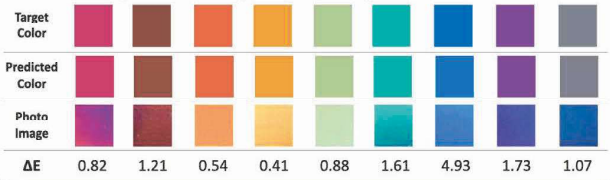
- **ΔE Histogram**



- **Scatter plots with correlation in CIE L*a*b* color**



- **Visual comparison of target colors and predicted colors**



研究生活及心得

非常感謝中技社提供這個寶貴的機會，也感謝評委們的青睞。也非常感謝陳鴻文教授、HW GROUP的成員們和朋友，他們的支持讓我在研究的道路上克服了重重困難，堅持不懈地前進。研究之路雖苦亦甜，但過程越是艱辛，成果的喜悅也越大。我很慶幸自己沒有放棄！未來將繼續拓展AI和深度學習的創新應用，在充滿挑戰的道路上努力前行。