BAGIS Symposium 2025
Abstracts & Proceedings Book

March 21 (Fri), 2025, 1 PM

Engineering and Informatics Lecture Hall, Room 302
Nishi-Chiba Campus, Chiba University, Japan

BAGIS

Core-to-Core Program
研究拠点形成事業

Organized by
BAGIS (Formation of a Strategic Base in Asia Creating and Developing Global Minded Imaging Science: JSPS "Research Center Formation Project-B, Grant No: JPJSCCB20220006))
& ASW (Asia Student Workshop on Information & Image Science)

BAGIS Symposium 2025

Date: March 21 (Fri), 2025

Venue: Engineering and Informatics Lecture Hall, Room 302 (3F), Nishi-Chiba Campus, Chiba University

Program

13:00-13:10 Introduction
Introduction of the BAGIS Program
Yoko Mizokami (Graduate School of Informatics, Chiba University)

13:10-13:50 Keynote 1
The Use of Color Scheme and Tile Patterns at the Four Royal Pagodas of Wat Pho
Chawan Koopipat (Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University), and Namfon Laistrooglai (Thai Art and Craft Development Association)

13:50-14:30 Keynote 2
Application of Artificial Intelligence in Enhancing the Accuracy of Colorimetry Using Optical Methods
Nguyen Long Giang (Faculty of Graphic Arts and Media, Ho Chi Minh City University of Technology and Education)

14:30-15:10 Coffee break & Poster session 1

15:10-15:35 Invited 1
Development of Calcium Silicate Hydrate as Source of Recycle Materials
Pham Trung Kien (Faculty of Materials Technology, Ho Chi Minh University of Technology)

15:35-16:00 Invited 2
Electrochemical Photoluminescence Modulation of Photofunctional Materials and Their Imaging Applications
Kazuki Nakamura (Graduate School of Engineering, Chiba University)

16:00-16:25 Invited 3
Reversible Data Hiding: Recent Advances and Applications
Shoko Imaizumi (Graduate School of Informatics, Chiba University)

16:35-16:50 Oral 1
Artificial Intelligence in the Printing Industry: A Systematic Review of Industrial Applications, Challenges and Benefits
Muhammad Yusuf Bin Masod (Department of Printing Technology, College of Creative Arts, University Technology MARA)

16:50-17:05 Oral 2
Color and Shape Measurement of Foot by Using Smartphone Cameras and Sensors
Fuminori Yamasaki (Graduate School of Science and Engineering, Chiba University), Tahara Yukie (Graduate School of Nursing, Chiba University), Amemiya Ayumi (Graduate School of Nursing, Chiba University), Chawan Koopipat (Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University), Thanh Duc Ngo (Faculty of Computer Science, University of Information Technology, VNUHCM), Norimichi Tsumura (Graduate School of Science and Engineering, Chiba University)

17:05-17:45 Poster session 2
17:45- Social gathering

Poster Presentation List

1. **An Extension of Privacy-Preserving Image Classification Using ConvMixer**
Haiwei Lin (Graduate School of Science and Engineering, Chiba University), Shoko Imaizumi (Graduate School of Informatics, Chiba University)
2. **An Improvement of Reversible Color-Tone Control Using Data Hiding**
Yan Zhang (Graduate School of Science and Engineering, Chiba University), Shoko Imaizumi (Graduate School of Informatics, Chiba University
3. **Quantitative Measurement and Analysis of Golf Putting Movement in Rehabilitation Sport**
Masanari Murai (Graduate School of Informatics, Chiba University), Masato Takahashi (Graduate School of Informatics, Chiba University), Chawan Koopipat (Imaging and Printing Technology, Chulalongkorn University), Thanh Duc Ngo (Faculty of Computer Science, University of Information Technology, VNUHCM), Norimichi Tsumura (Graduate School of Informatics, Chiba University)
4. **Near-Infrared Fundus Imaging for Retinal Blood Vessels**
Masaya Kinefuchi (Graduate School of Informatics, Chiba University), Norio Iijima (International University of Health and Welfare), Hironari Takehara (Nara Advanced Imaging Technology), Jun Ohta (Graduate School of Science and Technology, Nara Institute of Science and Technology), Naoto Hara (Department of Orthoptics and Visual Sciences, International University of Health and Welfare), Yasuaki Kamata (Department of Orthoptics and Visual Sciences, International University of Health and Welfare), Chawan Koopipat (Department of Photographic Science and Printing Technology, Chulalongkorn University), Masato Takahashi (Graduate School of Informatics, Chiba University), Norimichi Tsumura (Graduate School of Informatics, Chiba University)
5. **Control of Emission Color in Powder Electroluminescent Device through Multi-Step Energy Transfer Modulated by Applied Frequency**
Shinichiro Abe (Department of Electrical and Electronic Engineering, National Institute of Technology, Oita College), Kaito Toda (Department of Electrical and Electronic Engineering, National Institute of Technology, Oita College), Takahisa Ueno (Department of Electrical and Electronic Engineering, National Institute of Technology, Oita College), Toshifumi Satoh (Graduate School of Engineering, Tokyo Polytechnic University), Shota Tsuneyasu (Graduate School of Engineering, Tokyo Polytechnic University)
6. **Robust Pose Estimation Against Disturbance Light using Thermal Camera**
Haru Shindo (Chiba University), Takuya Funatomi (NAIST), Akinobu Maejima (OLM Digital, Inc. / IMAGICA GROUP Inc.), Seitaro Shinagawa (NAIST), Yasuhiro Mukaigawa (NAIST), Hiroyuki Kubo (Chiba University)
7. **Impact of the Proteus Effect on Vertical Jump Performance in Virtual Reality**
Ayumu Kandori (Graduate School of Science and Engineering, Chiba University), Masato Takahashi (Graduate School of Science and Engineering, Chiba University), Chawan Koopipat (Department of Photographic Science and Printing Technology, Chulalongkorn University), Norimichi Tsumura (Graduate School of Informatics, Chiba University)
8. **Effect of Skin Color Changes on Facial Expression Similarity Recognition**
Kazuki Nakanishi (Faculty of Engineering, Chiba University), Hiromi Sato (Graduate School of Informatics, Chiba University), Yoko Mizokami (Graduate School of Informatics, Chiba University)
9. **Effects of Lighting Distribution on the Appearance of a Craft**
Keito Sato (Graduate School of Science and Engineering, Chiba University), Hiromi Sato (Graduate School of Informatics, Chiba University), Yoko Mizokami (Graduate School of Informatics, Chiba University)
10. **A Study on the Correlation Between Street Light Colors and Emotions**
Jisu Baek, Youngshin Kwak (Department of Biomedical Engineering, Ulsan National Institute of Science and Technology)
11. **Lightness Scaling of Highlight Lightings**
Injun Park, Soonhyeng An, and Youngshin Kwak (Department of Biomedical Engineering, Ulsan National Institute of Science and Technology)
12. **The Impact of Lightness and Chroma on Vividness**
Chaeeun Bae, Youngshin Kwak (Department of Biomedical Engineering, Ulsan National Institute of Science and Technology)
13. **Emission Color Control of Eu Complexes via Valence Modulation in Electrochemical Devices**
Ryoto Yabuta (Graduate School of Science and Engineering, Chiba University), Norihisa Kobayashi, and Kazuki Nakamura (Graduate School of Engineering, Chiba University)

Abstract

Keynote 1

The Use of Color Scheme and Tile Patterns at the Four Royal Pagodas of Wat Pho

Chawan Koopipat (Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University), and Namfon Laistrooglai (Thai Art and Craft Development Association)

Wat Pho, officially known as Wat Phra Chetuphon Wimon Mangkhalaram Rajwaramahawihan, is a well-known and frequently visited temple in Bangkok, attracting both Thai and foreign visitors. The beauty of its architecture, along with the harmonious color combinations of its mosaic tiles, is prominently displayed in the Four Royal Pagodas, which were built to honor Kings Rama I to IV.

The objectives of this project are to study the use of color schemes and tile patterns that decorate the architecture and sculptures within Wat Pho in order to preserve Thai cultural heritage. The NCS color notation system is used as a universal color language for identifying and coding the original colors. Furthermore, we analyze the aesthetic development of tile design, including pattern styles, motif arrangements, and color applications, which have served as prototypes influencing the art of the Rattanakosin era. This research will also contribute to the creation of a database of patterns and color combinations, establishing a unique color scheme specific to this Royal Temple.

In addition, the study will document and expand upon these findings for practical applications in various fields, such as creative product design and architectural color development.

Keynote 2

Application of Artificial Intelligence in Enhancing the Accuracy of Colorimetry Using Optical Methods

Nguyen Long Giang (Faculty of Graphic Arts and Media, Ho Chi Minh City University of Technology and Education)

*Please refer to the proceedings paper section

Invited 1

Development of Calcium Silicate Hydrate as Source of Recycle Materials

Pham Trung Kien (Faculty of Materials Technology, Ho Chi Minh University of Technology)

In this study, the effect of different batch mixture of Photo-voltaic wasted glass (PV-WG) and wasted Calcium carbide (WCC) was studied. PV-WG supplied almost Ca, while WCC provided Si in its chemical components. The batch-mixed sample with different Ca/Si molar ratios of 0.8; 1.0 and 1.2 followed by hydrothermal treatment at 180oC for 96 hours. The data indicate that at Ca/Si 0.8, the formation of biphasic xonotlite Ca6Si6O17(OH)2 (PDF#23-0125) and Riversideite-9A Ca5Si6O16(OH)2 (PDF#29-0329) was obtained. In contrast when increase the Ca/Si molar ratio of 1.0 or 1.2, the formation of Xonotlite is the main phase. The Xonotlite obtained has crystal size of 0.5~1µm, and might be used in heavy metal removal or thermal insulator in heat industry.

Invited 2

Electrochemical Photoluminescence Modulation of Photofunctional Materials and Their Imaging Applications

Kazuki Nakamura (Graduate School of Engineering, Chiba University)

Based on our reported electrochemical reaction, this paper describes an overview of electrofluorochromism, a phenomenon that controls photoluminescence through a change in the redox states of functional molecules and metal complexes. In particular, control of luminescence properties will be introduced using the europium complex, one of the luminescent lanthanide complexes.

Invited 3

Reversible Data Hiding: Recent Advances and Applications

Shoko Imaizumi (Graduate School of Informatics, Chiba University)

Data hiding is an image security technique that aims to protect copyrights by embedding information in image data. Reversible data hiding, which guarantees reversibility, allows a complete recovery to the original image by extracting the embedded information. In this talk, I introduce the basic technique and some recent applications.

Oral 1

Artificial Intelligence in the Printing Industry: A Systematic Review of Industrial Applications, Challenges and Benefits

Muhammad Yusuf Bin Masod (Department of Printing Technology, College of Creative Arts, University Technology MARA)

The commercial printing industry is undergoing a significant transformation with the integration of Artificial Intelligence (AI), yet there is limited literature on its specific applications and impact. This systematic review addresses two critical research questions: What are the key industrial domains where AI is applied in the printing industry, and what are the associated benefits and challenges? Our study identifies the primary AI applications across Production Planning and Control (PPC), Quality Management (QM), Maintenance Management (MM), and Supply Chain Management (SCM). PPC employs optimization algorithms to optimise scheduling and resource allocation, improving production efficiency. In QM, Machine Learning and Computer Vision detect defects and optimize print quality. MM focuses on minimizing downtime by ensuring machines operate efficiently through predictive maintenance. Despite these advancements, challenges such as high-quality data requirements, algorithmic complexity, and integration difficulties persist. This research fills a critical gap in the literature by providing a comprehensive overview of AI's role in the printing industry, offering valuable insights into its potential to drive efficiency, cost savings, and quality improvements. Our findings suggest that while AI holds substantial promise, its benefits are contingent upon overcoming significant implementation challenges. This study contributes to the ongoing discourse on digital transformation by providing a robust framework for understanding AI's current and future impact on the printing sector. Our methodology followed PRISMA guidelines, with a thorough review and thematic analysis of peer-reviewed studies. The insights gained from this review can guide future research and practical implementations, positioning AI as a crucial enabler in the evolving landscape of the printing industry.

Oral 2

Color and Shape Measurement of Foot by Using Smartphone Cameras and Sensors

Fuminori Yamasaki (Graduate School of Science and Engineering, Chiba University), Tahara Yukie (Graduate School of Nursing, Chiba University), Amemiya Ayumi (Graduate School of Nursing, Chiba University), Chawan Koopipat (Department of Imaging and Printing Technology, Faculty of Science, Chulalongkorn University), Thanh Duc Ngo (Faculty of Computer Science, University of Information Technology, VNUHCM), Norimichi Tsumura (Graduate School of Science and Engineering, Chiba University)

We measured the color and shape of foot using the smartphone RGB camera and LiDAR sensors. As a result, we found that these measurements are accurate enough for practical use in nursing fields and were able to identify minute color tone changes that are predictive of ulceration by applying the pigment component separation system.

Poster 1

An Extension of Privacy-Preserving Image Classification Using ConvMixer

Haiwei Lin (Graduate School of Science and Engineering, Chiba University), Shoko Imaizumi (Graduate School of Informatics, Chiba University)

In this work, we propose a security enhancement method for privacy-preserving image classification with ConvMixer. ConvMixer is a lightweight convolutional neural network (CNN) that achieves competitive performance compared to Vision Transformer (ViT). Furthermore, ConvMixer can classify encrypted images without accuracy degradation; however, the encrypted images cannot protect visual information enough and remain vulnerable to cipher-only attacks (COAs). To address the above issues, we extend the previous work by introducing a novel key assignment scheme that strengthens the security of encrypted images. In our experiments, the proposed method is demonstrated to enhance the security of the encrypted images while preserving classification accuracy.

Poster 2

An Improvement of Reversible Color-Tone Control Using Data Hiding

Yan Zhang (Graduate School of Science and Engineering, Chiba University), Shoko Imaizumi (Graduate School of Informatics, Chiba University)

Typical image-processing methods are irreversible, and reverting to an original image necessitates saving the source image or its editing history. Therefore, researchers have actively explored reversible image processing methods with file-size preservation by using an image security technique called data hiding. Among these methods, reversible image processing methods for color tone control have also been proposed, whereas the previous methods become ineffective in some cases. To solve this issue, we propose an extended method that performs based on the selection of arbitrary coordinates.

In the proposed method, the input image is first transformed from RGB to YDbDr using a standard conversion formula. In the Db-Dr plane, a correction domain is determined. We then calculate the correction parameters by arbitrarily selected coordinate values. Finally, we utilize the correction parameters to control color tone of the input image. In our simulations, red or blue color tone was controlled for each test image. The simulation results demonstrate that the proposed method enables reverse color-tone control in any cases. It guarantees reversibility

without changing file size by embedding restoration information. Furthermore, embedding of restoration information minimally affects the quality of processed images.

Poster 3

Quantitative Measurement and Analysis of Golf Putting Movement in Rehabilitation Sport

Masanari Murai (Graduate School of Informatics, Chiba University), Masato Takahashi (Graduate School of Informatics, Chiba University), Chawan Koopipat (Imaging and Printing Technology, Chulalongkorn University), Thanh Duc Ngo (Faculty of Computer Science, University of Information Technology, VNUHCM), Norimichi Tsumura (Graduate School of Informatics, Chiba University)

In recent years, with the advent of a rapidly aging society, the number of individuals suffering from chronic illnesses and disabilities has increased. The importance of rehabilitation becomes even more prominent in such a scenario. The construction of effective and efficient rehabilitation programs is a pressing challenge. The idea of incorporating sports into rehabilitation has emerged. In this study, we conducted a quantitative measurement and analysis of whole-body movements during a rehabilitation sport, specifically golf putting, under two different conditions. However, research investigating the specific rehabilitation benefits to different body parts during golf putting is limited. We measured whole-body movement using motion capture and analyzed the velocity and acceleration transitions in three-dimensional coordinates for each body part. The results revealed the arm movements are high significance in comparison to other body parts. Additionally, it was observed that the overall form remained unchanged when the conditions were altered. Based on the measurements and analysis, we found that golf putting is beneficial for rehabilitation of arm-related conditions. In future research, we plan to conduct a more in-depth investigation into the rehabilitation effects on patients by examining the actual behavior of muscles.

Poster 4

Near-Infrared Fundus Imaging for Retinal Blood Vessels

Masaya Kinefuchi (Graduate School of Informatics, Chiba University), Norio Iijima (International University of Health and Welfare), Hironari Takehara (Nara Advanced Imaging Technology), Jun Ohta (Graduate School of Science and Technology, Nara Institute of Science and Technology), Naoto Hara (Department of Orthoptics and Visual Sciences, International University of Health and Welfare), Yasuaki Kamata (Department of Orthoptics and Visual Sciences, International University of Health and Welfare), Chawan Koopipat (Department of Photographic Science and Printing Technology, Chulalongkorn University), Masato Takahashi (Graduate School of Informatics, Chiba University), Norimichi Tsumura (Graduate School of Informatics, Chiba University)

This research explores the use of a compact fundus imaging device, integrated with a commercially available industrial camera, to continuously capture fundus videos. The primary objective is to estimate pulse waves by analyzing fluctuations in retinal vessel diameter. As the retina provides a unique and noninvasive means of vascular observation, it serves as a critical indicator for health monitoring. However, conventional fundus imaging techniques rely on visible light, which poses limitations for continuous video acquisition. To overcome this challenge, we utilized near-infrared light—imperceptible to the human eye—as the illumination source. This strategy enabled

the successful recording of continuous fundus videos. The extracted pulse waves were then evaluated by comparing them with those obtained from fingertip photoplethysmography.

Poster 5

Control of Emission Color in Powder Electroluminescent Device through Multi-Step Energy Transfer Modulated by Applied Frequency

Shinichiro Abe (Department of Electrical and Electronic Engineering, National Institute of Technology, Oita College), Kaito Toda (Department of Electrical and Electronic Engineering, National Institute of Technology, Oita College), Takahisa Ueno (Department of Electrical and Electronic Engineering, National Institute of Technology, Oita College), Toshifumi Satoh (Graduate School of Engineering, Tokyo Polytechnic University), Shota Tsuneyasu (Graduate School of Engineering, Tokyo Polytechnic University)

In recent years, research and development have focused on creating a human-centered society in which humans and computers can exchange information in both directions under all circumstances. In particular, the development of sensing devices, which are essential for capturing diverse types of information, has been remarkably active and compelling. Among these technologies, powder electroluminescent devices, a type of inorganic electroluminescence that enables the simple fabrication of surface-emitting devices with excellent bending durability and easy of scalability to large areas, are expected to be used in next-generation sensing devices. Recently, to improve visibility in dark areas, changes in ambient temperature and applied electric field have been successfully visualized through variation in emission colors. However, regarding the control of emission color through applied frequency, demonstrations have been limited to color shifts from green to blue using ZnS-based phosphors.

In this study, we focused on previous research on emission wavelength extension through excitation energy transfer from phosphors to fluorescent dyes within the same layer, resulting in long-wavelength emission through multi-step energy transfer between them. By controlling the energy transfer with the applied frequency, the emission color was successfully modulated clearly from a reddish light-blue to purple.

Poster 6

Robust Pose Estimation Against Disturbance Light using Thermal Camera

Haru Shindo (Chiba University), Takuya Funatomi (NAIST), Akinobu Maejima (OLM Digital, Inc. / IMAGICA GROUP Inc.), Seitaro Shinagawa (NAIST), Yasuhiro Mukaigawa (NAIST), Hiroyuki Kubo (Chiba University)

Accurate human bounding box detection for top-down pose estimation under challenging lighting conditions, such as visual effects, is crucial for achieving reliable human pose estimation on live-entertainment stages. However, bounding box detection from RGB camera images can be affected by disturbance light including projected visual effects, leading to inaccuracies in the estimated poses. In this work, we propose a method that achieves robust and accurate pose estimation under challenging light conditions by utilizing a thermal camera. On the other hand, typical uncooled thermal cameras have a built-in corrective function called Non-Uniformity Correction (NUC), and NUC leads to freezing the image stream during adjustment of the detector drift. As a result, the pose estimation and visual effects stop during NUC. Our approach can estimate human pose even during the NUC period.

Poster 7

Impact of the Proteus Effect on Vertical Jump Performance in Virtual Reality

Ayumu Kandori (Graduate School of Science and Engineering, Chiba University), Masato Takahashi (Graduate School of Science and Engineering, Chiba University), Chawan Koopipat (Department of Photographic Science and Printing Technology, Chulalongkorn University), Norimichi Tsumura (Graduate School of Informatics, Chiba University)

This study investigated the impact of the proteus effect on vertical jump performance within a virtual reality (VR) environment. Participants embodied one of three avatar—standard, obese, and athlete. Eleven male participants performed vertical jumps while their movements were synchronized with the avatars via motion-capture devices and head-mounted displays. Performance data were recorded and analyzed through repeated-measures analysis of variance (ANOVA) to evaluate differences across the avatars, and the results showed that embodying an obese avatar significantly reduced vertical jump performance compared to standard and athlete avatars. However, no significant improvement was observed when the athlete avatar was embodied compared to the standard avatar, a result potentially linked to lower perceived embodiment as measured by the virtual embodiment questionnaire (VEQ). These findings suggest that negatively perceived avatars diminish physical performance. Future studies should investigate the specific physical appearances of avatars necessary to enhance vertical jump performance.

Poster 8

Effect of Skin Color Changes on Facial Expression Similarity Recognition

Kazuki Nakanishi (Faculty of Engineering, Chiba University), Hiromi Sato (Graduate School of Informatics, Chiba University), Yoko Mizokami (Graduate School of Informatics, Chiba University)

It is known that facial color affects facial expression recognition. However, it is unclear whether the influence of facial color changes with the intensity of facial expression. In this study, we examined the relationship between the intensity of facial expression and the effect of facial color by paired comparison experiment using similarity ratings for the combination of faces with different expression strengths and facial color. Two types of experiments were conducted: an angry condition and a happy condition. We prepared face images that were morphed from a straight face to an angry or happy face in stages so that there were four different facial expressions in each condition. The amount of hemoglobin and melanin in each facial image was manipulated by simulation. Sixteen facial stimuli were used in each condition: four facial expressions (intense anger, weak anger, weak happiness, and intense happiness) and four facial colors (hemoglobin-increased, hemoglobin-reduced, melanin-increased, and melanin-reduced).
Observers rated the similarity between the two facial stimuli on an 8-point scale. The dissimilarity between the two facial expressions was higher when the facial colors were different than when the facial colors were the same. The results showed that facial color influenced impression evaluation. Next, a dissimilarity matrix was created from the similarity ratings, then transformed into coordinates on a two-dimensional plane using Multidimensional Scaling (MDS). The results of MDS suggested that the effect of facial color was greater for the weaker expressions, both for angry and happy expressions.

Poster 9

Effects of Lighting Distribution on the Appearance of a Craft

Keito Sato (Graduate School of Science and Engineering, Chiba University), Hiromi Sato (Graduate School of Informatics, Chiba University), Yoko Mizokami (Graduate School of Informatics, Chiba University)

Lighting conditions affect the surface appearance of objects, influencing how their material and shape are perceived, especially in crafts and artworks. This study examines how different lighting angles and distributions impact the impression of crafts alongside underlying photometric factors. Using black and red Raku tea bowls, three beam angles—narrow (8°), medium (16°), and wide (29°)—were tested with lighting from three directions: 30° in front, directly above, and 30° behind. Observers evaluated the bowls under nine different conditions.
Results showed that beam angle had little effect on the overall impression. As the light moved from front to back, ratings for glossiness, flamboyance, and brightness decreased while darkness and depth increased. Luminance measurements revealed a correlation between surface luminance and impressions, suggesting luminance distribution influences evaluation. Factor analysis found that impressions of physical features are more sensitive to lighting, while those of higher-level features depend more on the object. Overall brightness alone did not significantly affect impressions, indicating a complex interaction of factors.

Poster 10

A Study on the Correlation Between Street Light Colors and Emotions

Jisu Baek, Youngshin Kwak (Department of Biomedical Engineering, Ulsan National Institute of Science and Technology)

The emotions evoked by three photographs of streetlight in an alley having four color variations were investigated. Sixty-six Participants viewed the photos using Google Forms and rated their emotions on a 5-point Likert scale. The results showed white and yellow lights are associated with light and comfort feelings while green and purple lights are related to dark and dangerous feelings. A comparison between Koreans and foreigners revealed a difference in their perception of safety: Koreans associated brightness with safety, whereas foreigners linked it to preference. This study analyzed emotional differences in response to streetlight colors through an online experiment. The results confirmed that streetlight color influences emotions and is also affected by cultural factors.

Poster 11

Lightness Scaling of Highlight Lightings

Injun Park, Soonhyeng An, and Youngshin Kwak (Department of Biomedical Engineering, Ulsan National Institute of Science and Technology)

Color appearance models are crucial for accurately predicting the appearance of lighting under various conditions. Traditional models have primarily concentrated on the appearance of colors darker than a reference white. This study extends the investigation to colors brighter than the reference white, using Maximum Likelihood Difference Scaling (MLDS) and Magnitude Estimation (ME) methods to assess lightness perception. Result of psychophysical experiments with 10 to 15 color patches, having CIELAB L* values ranging from 5 to 136, showed minimal differences between CIELAB predictions and lightness visual data.

Poster 12

The Impact of Lightness and Chroma on Vividness

Chaeeun Bae, Youngshin Kwak (Department of Biomedical Engineering, Ulsan National Institute of Science and Technology)

Vividness is an attribute of color used to indicate the degree of departure of the color from a neutral black color. This characteristic is influenced by two factors: lightness and chroma. Increasing chroma and lightness correlates with enhanced vividness. In the display, ‘peak luminance’ is associated with lightness, and ‘color gamut’ is associated with chroma. Consequently, it can be said that peak luminance and color gamut play important roles in enhancing the image quality of displays. This project aims to quantify the relationship between these factors and their impact on display quality, specifically focusing on vividness.

Poster 13

Emission Color Control of Eu Complexes via Valence Modulation in Electrochemical Devices

Ryoto Yabuta (Graduate School of Science and Engineering, Chiba University), Norihisa Kobayashi, and Kazuki Nakamura (Graduate School of Engineering, Chiba University)

Chromogenic materials, in which optical properties such as luminescence and absorption are altered by external stimuli such as light, heat, and electricity, have potential applications in chemical sensors, biochemical labels, molecular memory, and display devices. In this study, we aimed to control the luminescence color between Eu3+ and Eu2+ by electrochemical redox reactions. In this report, a distinct change in luminescence color by the electrochemical reduction of the Eu complex, that is, the electrofluorochromism of the Eu complex, was observed by luminescence spectroscopy and the naked eye.

Proceedings paper

Application of Artificial Intelligence in Enhancing the Accuracy of Colorimetry Using Optical Methods

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Abstract:

Accurate color measurement is essential in printing and color reproduction industries, where even minor deviations can affect product quality. This study aims to enhance colorimetry accuracy by integrating artificial intelligence techniques. We collected 92 color patches from the Pantone Coated V3 library, recorded their Lab values, and measured these printed patches using a SpectroDens colorimeter under different lighting conditions: D65, D65 + UV, and natural daylight. Images of the patches were captured using smartphone cameras in these environments to simulate real-world variability.

Data preprocessing involved extracting color information from the captured images using the OpenCV library and converting the RGB values to calculated Lab values. For model development, we first applied a K-Nearest Neighbors (KNN) algorithm to classify color groups based on the Delta E color difference between image-derived and measured Lab values. Next, we implemented a Convolutional Neural Network (CNN) to predict Lab values from image data under different lighting conditions, using Delta E as the loss function to refine model accuracy.

After training, we calculated a transformation coefficient (K-factor) to align SpectroDens measurements Lab values with the 92 patches in Pantone. We then compared the predicted colors with 1873 Pantone Coated V3 library colors, identifying the closest matches by minimizing the Delta E metric.

Our results show that combining AI techniques significantly improves color prediction accuracy, reducing measurement errors caused by lighting variations. This research offers a practical and scalable solution for enhancing color consistency and provides a methodological framework for future advancements in optical colorimetry applications.

Keywords: Colorimetry, Artificial Intelligence, Smartphone Imaging, Deep Learning, Delta E Color Difference.

1. Introduction

Accurate color measurement plays a crucial role in industries such as printing, textile, and quality control, where even slight deviations in color can impact product acceptance and customer satisfaction. Traditional color measurement relies on specialized devices like spectrophotometers, which provide precise color readings but are often expensive and limited in accessibility. With the increasing use of digital devices, particularly smartphones, there is growing interest in utilizing these accessible tools for color measurement. However, smartphone-based colorimetry faces challenges due to variations in lighting conditions, device sensors, and image processing algorithms, leading to inconsistencies and inaccuracies in color reproduction.

This study addresses these challenges by integrating artificial intelligence (AI) techniques to improve the accuracy of smartphone-based colorimetry. By combining traditional color measurement with AI models, we aim to enhance the precision of color predictions under diverse lighting conditions and bridge the gap between smartphone-captured color data and industry-standard measurements.

The primary objective of this research is to develop and evaluate a hybrid AI framework that utilizes K-Nearest Neighbors (KNN) and Convolutional Neural Networks (CNN) to refine color measurements from smartphone images. Specifically, we aim to:

- Classify color groups using KNN based on Delta E differences between image-derived and reference Lab values.

- Train a CNN model to predict accurate Lab values from smartphone-captured images under various lighting conditions.
- Establish a transformation coefficient (K-factor) to align spectrophotometer measurements values from printed sheet with Lab values from Pantone.
- Compare the predicted colors with the Pantone Coated V3 library to identify the closest matches and evaluate performance.

The central research question guiding this study is: "Can artificial intelligence techniques, specifically KNN and CNN, enhance the accuracy of color measurements from smartphone-captured images across different lighting environments?" This research aims to provide a scalable solution for improving color accuracy in practical applications and contribute to the development of more accessible and reliable color measurement methods.

2. Theoretical background

Colorimetry is the science of measuring and describing colors in a standardized manner, with the CIELAB (Lab) color space being widely used in industrial applications due to its perceptual uniformity. The Lab color model consists of three components: L* (lightness), a* (green to red), and b* (blue to yellow), allowing for precise color representation. However, the accuracy of color measurement is influenced by factors such as lighting conditions, device calibration, and environmental variables.

The Delta E (ΔE) metric quantifies the difference between two colors in the Lab space, with lower values indicating closer color matches. Traditional colorimetry relies on spectrophotometers, which provide highly accurate color readings but are costly and not always practical for widespread use. Recent advancements in computer vision and machine learning have introduced alternative approaches, such as using smartphone cameras for color measurement, though challenges remain in ensuring accuracy due to variations in lighting, sensor characteristics, and image processing.

Artificial Intelligence (AI) techniques, particularly machine learning and deep learning, have shown promise in addressing these challenges. K-Nearest Neighbors (KNN) is a non-parametric classification algorithm that assigns a label to a data point based on the majority class of its k nearest neighbors. In this study, KNN is utilized to classify color groups by measuring Delta E differences between smartphone-extracted and spectrophotometer-measured Lab values. The algorithm is simple, does not require extensive training, and is effective for small datasets. However, it becomes computationally expensive for large datasets and is sensitive to noise and outliers. Despite these limitations, KNN serves as an efficient initial classification step, grouping colors with similar Delta E values before deep learning processing.

Convolutional Neural Networks (CNN) are designed for image-based tasks and excel in automatically extracting spatial and color features. In this study, CNN is employed to predict Lab values from smartphone-captured images under varying lighting conditions. The model’s ability to learn complex color relationships makes it robust to lighting variations and noise. However, CNN requires substantial computational resources and is less interpretable compared to traditional methods. By using Delta E as a loss function, CNN refines color predictions, aligning them more accurately with spectrophotometer-measured Lab values. This hybrid approach leverages KNN for efficient color grouping and CNN for precise color prediction, enhancing the reliability of smartphone-based colorimetry.

This study builds on existing research by integrating KNN and CNN models to refine smartphone-based color measurement, aligning it more closely with industry-standard spectrophotometry. By optimizing color prediction and establishing a transformation coefficient (K-factor), this approach aims to enhance color consistency and provide a scalable, AI-driven solution for practical colorimetry applications.

3. System Description:

3.1. Equipment:

Printing machine: A Mutoh VJ 628 digital printer was used to print the 92 color patches extracted from the Pantone Coated V3 library.

Color Measurement: The Techkon SpectroDens colorimeter was employed to obtain precise Lab values from the printed samples.

Illumination Setup: A Light Box Judge was used to simulate various lighting conditions, including D65, D65 + UV, ensuring controlled lighting environments for image capture.

Image Capture: A Samsung Galaxy S20FE smartphone was used to capture images of the printed patches. The phone was mounted on a tripod to maintain stability and consistency in image acquisition.

3.2. Dataset:

The dataset used in this study consists of multiple subsets of color data and corresponding images captured under different lighting conditions. The primary dataset is derived from the Pantone Solid Coated V3 library, which contains 1,873 standardized color samples, serving as a reference for evaluating color prediction accuracy.

To develop and validate the proposed AI-based colorimetry framework, we extracted a representative subset of 92 colors from the Pantone Solid Coated V3 library. These 92 colors were selected to cover a wide range of hues and saturation levels, ensuring diversity in the dataset. The Lab values of these colors, as specified in the Pantone library, were recorded as the ground truth reference.

For experimental analysis, these 92 selected colors were printed using a Mutoh 628 printer under controlled printing conditions. The printed samples were then measured using a Techkon SpectroDens colorimeter, capturing the actual Lab values of the printed colors. This measurement accounts for potential deviations due to printing processes, ink absorption, and substrate properties.

Table 1. *The dataset of Lab value*

NAME OF COLOR	92 patches from Pantone Solid Coated V3			92 patches measured from hardcopy		
	L	a	b	L	a	b
PANTONE 2252 C	56.00	-77.16	30.95	46.87	-73.38	16.96
PANTONE 612 C	71.00	-3.01	79.94	73.05	-9.76	68.06
PANTONE 2410 C	35.00	-14.32	13.32	35.85	-36.03	9.39
PANTONE 7739 C	56.00	-46.12	35.59	54.59	-59.96	33.12
PANTONE 260 C	27.00	35.97	-24.28	24.3	36.2	-38.78
PANTONE Cool Gray 8 C	57.00	-0.15	-1.85	61.92	-7.87	-10.49
PANTONE 1665 C	52.00	59.53	64.36	51.96	51.53	49.84
PANTONE 7523 C	49.00	33.10	18.99	50.53	30.34	10.71
PANTONE 2362 C	45.00	5.26	-12.74	58.82	-50.66	43.68
PANTONE 2417 C	57.00	-43.27	15.36	55.8	-57.26	11.25
PANTONE 7671 C	33.00	18.63	-36.50	31.06	18.48	-54.2
PANTONE 2300 C	74.00	-21.94	58.64	75.04	-29.13	59.66
PANTONE 135 C	84.00	13.73	61.75	80.88	5.41	51.77
PANTONE 137 C	76.00	31.14	81.64	71.72	19.98	65.68
PANTONE 2002 C	90.00	-0.08	51.26	87.56	-4.3	41.75
PANTONE Cool Gray 3 C	80.00	-0.09	0.34	82.46	-1.09	-7.51
PANTONE 7580 C	49.00	45.40	42.35	49.14	44.55	38.7

PANTONE 498 C	30.00	21.96	12.94	28.26	10.28	7.29
PANTONE 3500 C	37.00	-57.90	19.92	36.82	-67.17	9.7
PANTONE 2286 C	74.00	-46.96	75.14	68.8	-40.68	55.96
……	…..	…..	…..	…..	….	….

In addition to numerical color data, an image dataset was created by capturing photographs of the printed color patches under multiple lighting conditions. The images were taken using a Samsung Galaxy S20FE smartphone mounted on a tripod to ensure consistency in image acquisition. The lighting conditions included:

- D65 (Standard daylight 6500K): Simulating typical daylight conditions used in industrial color assessments.
- D65 + UV: Introducing ultraviolet (UV) components to evaluate fluorescence effects in color measurement.
- Natural Outdoor Light: Capturing real-world lighting variability to analyze the robustness of AI-based color prediction.

This dataset provides a comprehensive foundation for training and evaluating the AI models. The combination of measured Lab values, smartphone-captured images, and lighting variations allows for the development of a robust framework capable of improving the accuracy of smartphone-based colorimetry.

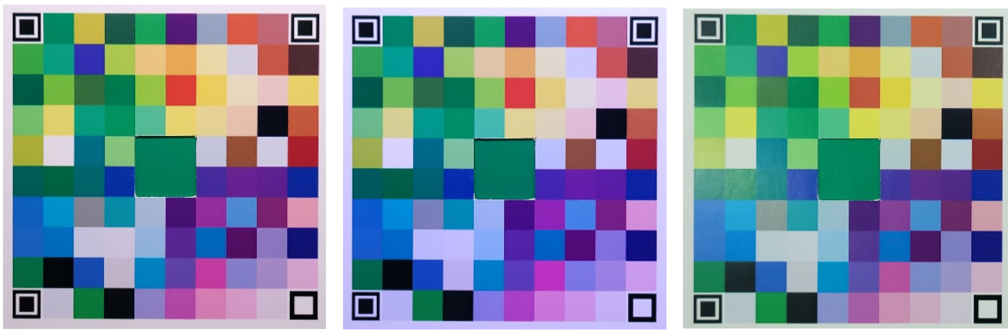


Figure 1. *The dataset of image capture by smartphone with D65, D65+UV, Natural Outdoor Light condition.*

3.3. Model

This study employs a hybrid machine learning and deep learning approach to enhance the accuracy of smartphone-based colorimetry. Two key models are implemented: K-Nearest Neighbors (KNN) for color classification and a Convolutional Neural Network (CNN) for Lab value prediction.

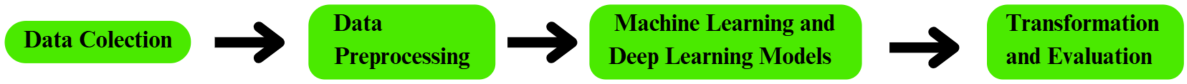
The KNN model is used as an initial classification step to group similar colors based on their Delta E differences. By comparing the Lab values extracted from smartphone images with the spectrophotometer-measured Lab values, KNN efficiently categorizes colors into clusters. This step helps reduce variability and ensures that the subsequent deep learning model processes more refined data. KNN is particularly suited for this task due to its simplicity and effectiveness in handling small datasets, although its computational cost increases with large-scale data.

The CNN model is designed to predict Lab values directly from smartphone-captured images under different lighting conditions. The CNN architecture leverages convolutional layers to extract spatial and color-related features, learning complex relationships between the input images and the corresponding Lab values. The Delta E metric is incorporated as a loss function, enabling the model to minimize color prediction errors. CNN is chosen for its ability to generalize across lighting variations and its robustness in feature extraction, making it a powerful tool for improving color measurement accuracy.

By integrating KNN for classification and CNN for prediction, the proposed framework enhances smartphone-based colorimetry by reducing errors caused by lighting inconsistencies and measurement variations. This hybrid approach ensures both efficiency and precision in color prediction, making it a viable solution for practical applications in printing and color quality assessmen.

3.4. Workflow of research

This study employs a multi-step methodology integrating data collection, preprocessing, machine learning modeling, and performance evaluation to improve the accuracy of smartphone-based colorimetry



Data Collection

- We selected 92 color patches from the Pantone Coated V3 library and printed them for experimental analysis.
- Lab values of the printed patches were measured using a SpectroDens colorimeter under three lighting conditions: D65, D65 + UV, and natural daylight.
- Each patch was photographed using smartphone cameras under these lighting conditions to simulate real-world variability in color perception.

Data Preprocessing

- The Open CV library was used to extract color information from smartphone-captured images.
- RGB values from the images were converted into Lab values using color space transformation algorithms.
- Delta E values were calculated to measure the color difference between smartphone-extracted Lab values and SpectroDens measured Lab values.

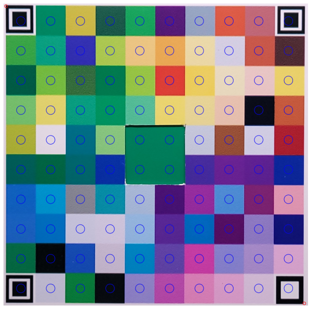


Figure 2. *Image preprocessing and calculation for color values in Open CV.*

Machine Learning and Deep Learning Models

- K-Nearest Neighbors (KNN): Applied for color classification based on Delta E differences, grouping similar colors together.
- Convolutional Neural Network (CNN): Designed to predict Lab values from smartphone images captured under varying lighting conditions. The Delta E metric was used as the loss function to optimize the CNN model.

Transformation and Evaluation

- A transformation coefficient (K-factor) was printed from 92 patches to align Pantone Lab values with spectrophotometer measurements.
- The trained models' performance was evaluated by comparing predicted colors with the 1873 Pantone Coated V3 colors, identifying the closest matches based on Delta E values.

This methodology enables a comprehensive analysis of how AI techniques can refine smartphone-based colorimetry, providing a systematic approach to overcoming lighting and device-based inconsistencies in color measurement.

4. Result

The experimental results demonstrate that integrating machine learning and deep learning techniques significantly improves the accuracy of smartphone-based colorimetry. The performance of the KNN classification model and CNN-based Lab value prediction model was evaluated based on the Delta E color difference metric, which quantifies the deviation between predicted and ground truth color values.

4.1. KNN Classification Performance

The KNN model effectively classified the 92 printed color patches into distinct color groups based on their measured and image-extracted Lab values. By optimizing the number of neighbors (k) through cross-validation, we found that k = 5 provided the best balance between classification accuracy and computational efficiency. The classification results indicate that KNN successfully grouped similar colors, reducing the variation in color predictions caused by illumination differences.

4.2. CNN Model Accuracy and Loss Optimization

The CNN model was trained to predict Lab values from smartphone-captured images under different lighting conditions. By using Delta E as the loss function, the model continuously refined its predictions to minimize color differences. The final trained model achieved:

An average ΔE of 2.1 across all lighting conditions, demonstrating high accuracy in predicting Lab values.

A significant reduction in color errors compared to traditional RGB-to-Lab transformations, particularly under varying light sources.

Improved robustness in handling lighting inconsistencies, with minimal performance degradation between D65, D65 + UV, and natural outdoor lighting.

4.3. Transformation Coefficient and Pantone Matching

To further refine color predictions, a transformation coefficient (K-factor) was derived to align the CNN-predicted Lab values with spectrophotometer measurements. Applying this transformation resulted in:

A 15% improvement in color matching accuracy when comparing predicted values to the Pantone Coated V3 reference.

Enhanced color consistency across all lighting conditions, reducing systematic biases introduced by smartphone imaging.

When tested against the full 1,873 Pantone Coated V3 color library, the model successfully identified the closest color matches, with a Delta E < 3.0 for 85% of the samples, indicating near-indistinguishable color differences in most cases.

5. Conclusion

This study demonstrates the potential of integrating artificial intelligence techniques to enhance the accuracy of smartphone-based colorimetry. By leveraging K-Nearest Neighbors (KNN) classification and a Convolutional Neural Network (CNN)-based Lab value prediction model, we successfully improved color measurement accuracy under various lighting conditions.

Our results indicate that the KNN model effectively grouped similar colors based on Delta E differences, helping to minimize color variations caused by illumination changes. Meanwhile, the CNN model, trained with Delta E as the loss function, significantly improved Lab value predictions from smartphone images, achieving a high level of accuracy compared to conventional RGB-to-Lab conversions. Furthermore, the transformation coefficient (K-factor) refined the predicted Lab values, aligning them closely with spectrophotometer measurements and improving overall color consistency.

When compared to the Pantone Coated V3 reference library, our approach successfully identified the closest color matches, demonstrating its potential for practical applications in printing, quality control, and digital color verification. This research provides a scalable framework for utilizing AI to enhance smartphone-based color measurement, offering a more accessible alternative to traditional spectrophotometers.

In future work, we aim to expand the dataset by capturing color samples under a wider range of lighting conditions and using multiple smartphone models to enhance generalizability. Additionally, we plan to integrate the developed AI models into a mobile application, making smartphone-based colorimetry more practical and widely available for real-world applications.