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Private University Research Branding Project supported by the Ministry of Education, Culture, Sports, Science and Technology for Fiscal Year 2016

Create Tomorrow, Learn Future, and Connect the World by “Color”, KOUGEI Color Science and Art

Greetings from the President

Ryuichiro Yoshie, President, Tokyo Polytechnic University

Tokyo Polytechnic University (TPU) originated as the “Konishi Professional School of Photography”, founded in 1923. It was established to train technicians and researchers in the field of photography, a cutting-edge expression technology at the time. The school was a pioneer in combining self-expression through photography (art) with photographic techniques (technology). It developed into a university consisting of two unique faculties, the Faculty of Engineering and the Faculty of Arts, and “technology-art fusion” is its unique characteristic.

TPU’s project, which was adopted for a Private University Research Branding Project (Type B “Global Development Category”) for fiscal year 2016, is rooted in academic disciplines such as photography, printing, and optics, which have been research fields of TPU since its founding. The project picks “color” as a cross-cutting research theme that is common in today’s Faculty of Engineering and Faculty of Arts. We have formed the only “International Research Center for Color Science and Art” in Japan. Especially, disseminating information by means of media art such as photography, video, augmented reality, projection mapping, computer graphics, manga, and games is a unique branding strategy only possible with TPU. We have established a gallery where visitors can experience the pleasure of learning the science of “color” with media art. We also have been hosting public lectures, international workshops, and research results presentation sessions under the theme of “color”. We hope to attract many people to these events.

Through this project, we will build a solid brand for our university to be known for “color” and aim for true “fusion of technology and art”. So please look forward to our activities from now on.

Greetings from the Director of the Center

Yasushi Noguchi, Professor, Faculty of Arts, Tokyo Polytechnic University

“Color” is mysterious. We think we understand it, but it has many unknown facets.

We tend to believe that the world exists as we see it in our everyday lives. But human beings can only see a part of the spectrum of electromagnetic waves falling on the earth. For example, we cannot “see” infrared or ultraviolet rays. However, some species of animals can. The world seen by those animals may be richer than the one we human beings see.

Seeing “color” seems to be self-evident, but, concerning its mechanism, there are more unknown things than known ones. In order to solve the mysteries of color and to link research results to new expressions, interdisciplinary activities that do not depend on conventional expertise are needed.

Originally, engineering and art were not separate fields, and each developed by receiving synergistic effects. Pictures, movies, CG, or interactive art would not have developed without the latest technology of that era. Especially in a cross-cutting theme like “color”, collaborative research of staff members of the Faculty of Engineering and the Faculty of Arts, which are the features of our university, will lead to development of new technologies and new expression. My role as the director of the Center is to provide an environment that produces such innovative research and production results.

It is also important to proactively release these results to the public (outreach activities). Therefore, in this project, we established an experience-based system for learning color and established a gallery (i.e. col.lab gallery) that makes the results public. In this gallery, we want visitors ranging from children to adults to experience scientific and artistic fun and depth of “color” and will establish a cycle to connect visitors’ reactions to new research.

Through research and production of “color” that utilize the characteristics of our university, we will make efforts to establish a firm brand for Tokyo Polytechnic University.

About the Private University Research Branding Project

The “Private University Research Branding Project” is a governmental program that lends intensive support for expenses, facility costs and equipment costs as a package to private universities working on unique research across the university under the leadership of the president. There were 198 applications from private universities nationwide. 17 schools were selected for “Type A (Social development category: Research that contributes to development and deepening of regional economy and society, employment, culture and other specific fields) and 23 schools including TPU were selected for “Type B (Global development category: Research that contributes to national or international economic and social development, and progress of science and technology through development of advanced and interdisciplinary research bases)”.

Invited Lecturers

Prof. John McCann (McCann Imaging, Arlington, MA, United States)

John McCann has always been interested in color. He separated colored salts by chromatography in a high school science-fair. He synthesized pale-blue and pink isomers of $CuCl_2$ in freshman independent-research at Harvard. He worked for Edwin Land on two-color photography and Retinex Theory during summers at Polaroid. He worked for Land for 20 years. After a Harvard degree in Biology in 1964, he managed Polaroid’s Vision Research Lab until 1996. Land and McCann worked with Ansel Adams to invent an algorithm to calculate photographic renditions mimicking Adams’ Zone System in 1971. John set up Polaroid's first digital imaging laboratory in 1975. He developed a system that captured natural scenes, calculated appearances, and wrote the computed image on media. This system converted >1000:1 scene ranges to the 30:1 range in prints. The Retinex model simulates what a painter would do to reproduce a scene. John’s work began with photography, progressed to papers in controlled illumination, to computational electronic imaging. He developed and patented efficient algorithms for making spatial comparisons among all pixels in an image. The idea connecting color, and HDR imaging is that appearance is controlled by spatial, multi-resolution processes. He is a Fellow of Imaging Science and Technology (IS&T) and Optical Society of America (OSA). He is a past president of IS&T and Artists Foundation, Boston. He is the IS&T/OSA-2002 Land Medalist and IS&T-2005 Honorary Member. He continues his research on color vision, photography, and fine art.

Prof. Kentaro Arikawa (SOKENDAI-Graduate University for Advanced Studies, Hayama, Japan)

Kentaro Arikawa is a professor of neuroethology at SOKENDAI. As a first-year graduate student of Sophia University, Tokyo, he discovered that butterflies can detect light with their genitals and studied this unique light-sensing system for his Ph. D. He then started to study color vision in butterflies. After being a biology professor at Yokohama City University for 21 years, he moved to SOKENDAI in 2006. He also served as a research fellow at Australian National University and the National Institutes of Health, USA. Besides science, he enjoys nature photography and flute playing.

Prof. Mark D. Fairchild (Founding Head, Integrated Sciences Academy
Professor & Director, Program of Color Science / Munsell Color Science Laboratory
Rochester Institute of Technology)

Mark D. Fairchild is a Professor and Founding Head of the Integrated Sciences Academy within RIT's College of Science and Director of the Program of Color Science and Munsell Color Science Laboratory. He received his B.S. and M.S. degrees in Imaging Science from R.I.T. and Ph.D. in Vision Science from the University of Rochester. Mark was presented with the 1995 Bartleson Award by the Colour Group(Great Britain) and the 2002 Macbeth Award by the Inter-Society Color Council for his research work in color appearance and other areas of color science. He is author of over 300 technical publications and the book, Color Appearance Models, 3rd Ed., which serves as a reference to the fundamentals of color appearance and the formulation of specific models. He served as Color Imaging Editor for IS&T's Journal of Imaging Science and Technology for 3 years and was named a Fellow of IS&T (the Society for Imaging Science and Technology) in 2003 for his contributions to digital color imaging. In 2007, Mark was presented with the Davies Medal by the Royal Photographic Society for his contributions to photography in the digital field of imaging science. He received the 2008 IS&T Raymond C. Bowman award for excellence in education and he was named a Fellow of the Optical Society of America in 2012 for his contributions to research and education in color and imaging sciences. In 2018 he received the Nickerson Service Award from the Inter-Society Color Council. He was chair of CIE Technical Committee 1-34 on color appearance models, is currently a member several other CIE technical committees dealing with color appearance and image technology issues. Mark has been an active member of IS&T, ISCC, CORM, CIE-USNC, OSA, SID, AAAS, VSS, and ACM-SIGGRAPH.

Prof. Yoko Mizokami (Chiba University, Japan)

Dr. Yoko Mizokami is a Professor in the Department of Imaging Sciences, Graduate School of Engineering, Chiba University, Japan. She received a Ph.D. in Engineering in 2002 from Ritsumeikan University, Japan. From 2002-2006 she was a postdoctoral fellow at the University of Nevada, Reno, Department of Psychology. She moved to Chiba University in 2006. She belongs to Vision Sciences Society, International Colour Vision Society, Optical Society of America, and Illuminating Engineering Institute of Japan, Optical Society of Japan, Vision Society of Japan, and Color Science Association of Japan. She is currently a member of the Board of Directors of the International Colour Vision Society and an official CIE Division 1 member. She is an associate editor of Color Research and Application. Her research interests lie in color vision, color science, and vision in natural environments. The current research topics cover the influence of lighting to object appearance, the perception of images, materials and skin, colorfulness adaptation, and color vision deficiency.

Art, Reproduction Technology, and Science: Foundations of Understanding Color

John McCann

McCann Imaging, Arlington, MA 02474, USA

ABSTRACT

Understanding Color is the fusion of today's imaging technology with our 160-century history of making pictures. Molecular physics describes the mechanisms of light-matter interactions, while painters and picture makers have led the way to understanding how we see Color. The painter's hand is controlled by his Color Vision. While Molecular Physics happens at the atomic scale, Color Vision is controlled by neurons interacting with the entire scene. The threads of Painting, Reproduction Technology, Physics, and human Color Vision weave together to make 2020's Color.

1. INTRODUCTION

Our understanding of Color is both practical and scientific. The practical part is the art of painting pictures, and the technology of reproducing scenes. The scientific part is the interaction of light and matter. Physics provides understanding of electromagnetic visible light (wavelengths between 400 and 700 nm). Some molecules (colorants) modify the wavelength distribution of the illumination's light. Other atoms and molecules emit light. All of color physics happens at a sub-microscopic, molecular scale. More important, these light /matter interactions at each location in the scene are independent of all other parts of the scene. In other words, *Molecular Physics* describes local events.

Color in practical Picture Making is different. It uses the viewer's entire visual system as the most important part of the process, whether painting a landscape, or making firmware for a camera. The picture's appearance is the output of the viewer's neural comparisons of all scene elements. Appearance (sensations) depends on the interaction of all of vision, and the entire scene. In other words, human vision uses light from all parts of the scene to make the appearance of each scene element. While local *Molecular Physics* events are necessary, vision also requires neural *Spatial Comparisons* made across the entire scene to make pictures. We know this because two identical spots of light can appear different colors in the same real-life scene.

Human fascination with Pictures Making goes back to man's earliest recorded history.

- Painting requires the combination of tools and human vision to guide the artist's hand in rendering appearances.
- *Printing* goes back to rubbings of the earliest coins, and embossed clay. An artist's hand made the master, and technology made identical copies.
- Physics describes the interaction of light and matter. Although discussed by the ancient Greeks, *Molecular Physics* has advanced most rapidly in the past three centuries.
- Color Vision research describes the mechanisms used in seeing: optics of the eye; retinal cells that respond to visible photons; nerve cell response, spatial comparison of neural response; sensations, and perceptions of color.

This talk studies these four different threads of Color. More important, it emphasizes how they weave together to influence, and advance each other. To understand Color, one has to study all of its historical threads. The long history of Picture Making is the story of artists painting and printing them. In 1800, photography and studies of light/matter interactions started the Molecular Physics technologies of film, digital sensors, and displays of today.

Picture Making's biggest challenge is rendering the real-world's High Dynamic Range (HDR) of light. Painters met that challenge in 1500, and physics-based technology is fighting with it today. This talk uses HDR imaging as a test of Picture Making, and a signature of human Color Vision's mechanisms.

2. SNAPSHOTS IN TIME

Color becomes much more interesting when we compare the threads at the same time in history. While painting and printing made significant developments centuries earlier, physics and color vision research have recently caught up in importance for the future. The following snapshot examples illustrates how these historical threads interacted.

In 1500, at the height of the Italian Renaissance, painting was revolutionized by the use of perspective and chiaroscuro (light and dark rendition). Perspective imposed scientific rules controlling the size relationships of objects in the scene. Leonardo da Vinci invented chiaroscuro to unify the rendition of light and shadows throughout a painting. This began the rendition of High Dynamic Range (HDR) pictures. Also, Leonardo observed that colors appear most beautiful when surrounded by their opposites.

Around 1700 Newton's physics experiments separated white light's different "refrangibilities" (wavelengths) that appear red, yellow, green, blue and violet colors. He used a second prism to recombine those wavelengths into white light. Newton's Color Vision observation was:

"For the Rays to speak properly are not coloured. In them there is nothing else than a certain Power and Disposition to stir up a Sensation of this or that Colour." [1] The double prism experiment, separated the physics of light from the action of human vision, namely "stirring up a Sensation". Also in 1700, Mezzotint printing plates became popular for their efficiency. By using different "rocker" tools to roughen metal plates, printers formed different tone textures, that transferred different amounts of ink to the print paper. LeBlon used three color, plus a black mezzotint plates to become the color printmaker for the French court. In Holland, Vermeer painted "Girl with Pearl Earring" rendering the model and the scene's illumination in a remarkable HDR portrait.

In 1802, Thomas Young wrote "On the Theory of Light and Colours" with a footnote suggesting that human Color Vision was trichromatic. That footnote does not explain his observation. Color-printing was everywhere in London at the time. LeBlon's 1707 Mezzotints show an example of theory following practice. in 1810, Goethe, the German poet, began a psychological branch of Color by attacking Newton's work and Newton's character. Rather than repeating Newton's experiments, Goethe held a prism in front of his eye. He did not understand what he saw. Goethe's reports about afterimages, and opponent colors emphasized human vision. Goethe missed Newton's statements about "stirring up Sensations". Nevertheless, he started two centuries of debate on the relative importance of light vs. vision.

Today, Molecular Physics has produced color pictures with remarkable improvements in the control of spectral light, with much better color purity and chroma. Color Vision research has provided many more details and measurements of Spatial Comparisons with the study of psychophysics and neurophysiology.

3. FRAMEWORK FOR UNDERSTANDING COLOR

Aristotle segmented his writing into books, each with related studies. This tradition of segmentation continues in Universities, with Departments, and Divisions, such as Arts, Humanities, Science, and Engineering. But, Color is an essential part of many studies. Color does not belong to a single field: It is a fusion of all of its different parts. It builds on the integration of the best elements of competing systems.

A good example of fusion is the complete transformation of Photography over the past 40 years. In 1980, the photographic film industry made many millions of cameras and billions of photographs. By 1990, many companies made massive investments in digital photography. In 2000, mature digital products began to replace almost all film. The features of cost per picture, access to stored images, customer behavior, and especially the ability of easy transport of images on the internet morphed a very mature film industry into an entirely different digital one. Digital photography fused the best elements of old and new into today's photography.

The history of Color is the fusion of Art, Picture Making, Physics and studies of Color Vision. Some of the most important contributors to understanding color made extraordinary contributions to more than one of its fields:

- Leonardo - Painting and Color Vision
- Newton - Physics of light and Color Vision
- Maxwell - Color Matching and Color Photography
- Land - Instant Photography and Color Vision

These students of color amplified their contributions by working in several fields. Newton's double prism experiment separated different wavelengths, and then recombined them. There, he identified light's physical properties. When he described what these wavelenths looked like, he knew that he was working in another field. Newton separated the physics of light from light's action in human vision, describing it as "stir up a Sensation".

Land was an expert in making silver halide and dye images. As soon as he saw the wide range of colors in red and white (2-color) photographs, he knew that the mechanisms controlling color appearance were fundamentally different from those controlling color in films. He knew that RGB separations, used since LeBlon, were made by local Molecular Physics interactions. He knew the human retinal receptors used the same physics-based mechanisms. Land recognized that Molecular Physics is necessary, but not enough to explain what we see. Additional mechanisms are needed to understand Color Appearance and Color Constancy. Land turned to *Spatial Comparisons across scene*.

Year	Reported by	Idea	Field
1000	Alhazon	Object's light imaged on the light sensitive retina	Optics
1500	Leonardo	"Colors are most beautiful surrounded by..."	Painting, Vision
1672	Newton	"The rays are not colored ..."	Physics, Vision
1707	J.C. LeBlon	4 color separation records, hand rockers	Color Printing
1828	Goethe	Prisms, Afterimages, Attacks on Newton	Writer
1861	J.C.Maxwell	3 color photographic separations made with RGB	Color Photo
1861	J.C.Maxwell	Measured 3 sensitivity functions -> CIE X,Y,Z	RGB sensitivity,
1872	Hering/Helmholtz	Debate about Constancy	Psychophysics
1949	Ansel Adams	Zone System	Photographer
1957	E.H. Land	Red and White - 2 color photography	Color vision
1963	E.H. Land	3 lightness separations to predict color - Retinex	Color vision
1967	Land & McCann	Ratio Product Reset model to predict lightness	Computer vision
1968	Hubel & Wiesel	Spatial processing in the Cortex	Neurophysiology
1978	Carver Mead	VLSI Chip design - Today's Computers	Computers
1983	Frankle & McCann	Multiresolution lightness model	Computer vision
2007	McCann & Rizzi	Calculated glare degraded retinal image Receptor and neural processing	Optics Matching

Fig. 1 List of author's foundational Ideas: Year, Idea, and Field of Study. (Historical references [2])

3.1 Personal Color Frameworks

Each of us has a personal Framework of Color. Fig.1 is the list of ideas that form the foundation of my thinking about color. It is made up of ideas from many different disciplines. In high school I loved Chemistry. In college I traveled from Chemistry to Biochemistry to Biology, while working part-time for Edwin Land at Polaroid. My work at Polaroid studied color vision, computer models of vision,, very-large format Polaroid cameras, and the reproduction of art. I set up Polaroid's first digital imaging lab in 1975 to model human *Spatial Comparisons*.

Fig. 1 is a list of essential ideas in my own research. I worked backwards from current interests to identify its most important foundations. The list includes original date, author who reported it, and the idea's Field. While these ideas are special for me, the more interesting list is the Fields they came from. It shows themes of interest in light and molecular physics, as well as how to understand vision and computer models of it. However, many of my important ideas are not main-stream to my themes. These ideas come from other Fields.

The first challenge in fusing different views is that each discipline uses its own vocabulary. Too often the same words have conflicting definitions. *Contrast* is a word common to all parts of color. But, photographers think of *Contrast* as the "*slope of response function"*, while electrical engineers think of it as "*black level setting"*. Painters, neurophysiologists, computer programmers add their own special meanings. Patience is necessary to wander into other Fields, particularly in learning the meaning of unfamiliar terminology.

Finding how to use the ideas from different Fields is rewarding. It can end needless debates, and generate insight and understanding. Try making your own Color Framework of the ideas that are most important to you.

3.2 Story of Color

The Framework in Fig. 1 leads to my condensation of research in color. The chain of events leads to seeing Color in a real-life scene:

- Light/matter interactions controls light reaching eye
    - **Molecular Physics**
- Optical Glare controls the image on the retina
    - **Glare Spread Function (GSF)**
- Receptors convert light to nerve response
    - **Molecular Physics**
- Neural processing
    - Counteracts Glare [3]
        - **Spatial Comparisons**
    - Controls Color Constancy [4]
        - **Spatial Comparisons**

The most common issue in understanding color results from applying the rules for *Molecular Physics* directly to the prediction of color appearance. Leonardo observed that Color Vision responds to the scene. This idea has been reinforced by LeBlon, Goethe, Herring, Land, Hubel & Wiesel, Dowling, and Campbell. *Molecular Physics* controls the light reaching the eye, and the response of receptor outer segments. But, it does not control appearance. There is no light from the surround in Maxwell's Colorimetry. Hence no glare, and the only *Spatial Comparison* is between the uniform spot to the minimal light surround.

Psychophysical measurements of the conversion of light to appearance have observed different results for different scenes. The appearances of spots of light lead to different models than real-world scenes. *Spatial Comparison* mechanisms are needed in real scenes and complex scene constructions.

4. CONCLUSIONS

Recent applications of *Molecular Physics* and engineering brought us today's color pictures. Color keeps getting better at a faster and faster rate. Nevertheless, understanding how we see Color remains a fascinating topic with problems to be solved. Understanding them needs our entire color history. While we recognize the many recent advances in *Molecular Physics*, we have a new appreciation of the role of neural *Spatial Comparisons*. Color photography's three separations are the result of *Molecular Physics*. Color Vision's three separations are the result of neural *Spatial Comparisons*. Light controls technology, but neurons control color appearance. Light/matter interactions happen in the space of molecules. Appearance involves processing the entire scene, so that models of vision demand data from all receptors. Both the mechanism, and the data required are important parts of understanding Color.

Two experimental studies are important in evaluating real-world vision: Color Constancy and HDR Color. Constancy works best in low-range scenes made of uniform reflectances. It has been measured and modeled successfully using *Spatial Comparisons*. Further, Color Constancy is inconsistent with retinal adaptation mechanisms.[5] Measurements of Color Constancy in HDR scenes have shown that edges in illumination (shadows and specular reflections) are seen the same as edges in reflectance. In HDR scenes Constancy is limited to local segments. Nevertheless, the *Spatial Comparisons* that compensate for glare combine with *Spatial Comparisons* for Constancy to model real-world color.

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The Introduction of the 5th Exhibition at the col.lab Gallery

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ABSTRACT

Observing is the act of actively approaching an object, and the results of observation vary according to the approach, so it can be thought of as similar to talking with the object. The 5th exhibition, "Talking with Color", held at the col.lab Gallery from Nov 19, 2019 to Apr 25, 2020, is an art exhibit in which viewers can feel as if they are interacting with color, such as by changing it autonomously or according to their behavior or subjectivity.

1. INTRODUCTION

When you look at flames, smoke, or waves as they gradually change in shape, aren't you drawn in and lose your sense of time passing? As your consciousness is entangled in things that change, such as life does, it appears that the objects being looked at have their own subjectivity separate from yours. Observing is the act of actively approaching an object, and the results of observation vary according to the approach, so it can be thought of as a dialogue. The theme of the 5th exhibition at the col.lab Gallery from Nov 19, 2019 to Apr 25, 2020 is "Talking with Color" [1]. This exhibit highlights art that helps viewers feel as if they are interacting with color, such as by changing it autonomously or according to their behavior or subjectivity.

2. THE ARTWORKS

2.1 The Dress

Supervising Editor: Yuta Ogai

The photo of "The Dress" became a hot topic on the Internet because its color appeared either as black/blue or white/gold in photos depending on the viewer. "The Dress" is on display with a system that allows the viewer to change the color of the LED light that illuminates it (Fig.1).

Fig. 1. The Dress

2.2 Chaotic Video Feedback

Author: Yuta Ogai

If you capture an image on a screen with a camera and display the captured image layered over the original screen image, a repetitive pattern like a coupled mirror emerges. A system using chaos mapping on each camera image to break repeated objects gradually over each loop is on display (Fig.2). The chaos mapping is a logistic map that converts the RGB or HSV value of each pixel to next state. Viewers can interact with the system by stepping into the repetitive screen and adjusting the mapping parameters themselves.

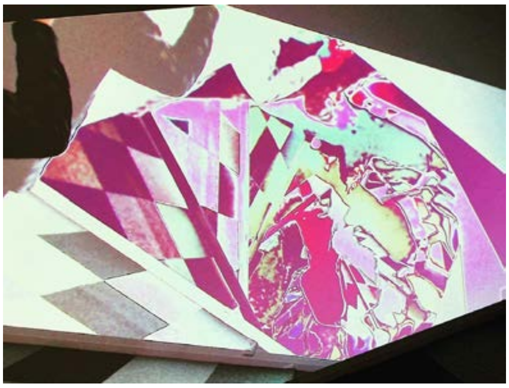

Fig. 2. Chaotic Video Feedback

2.3 DanceAI × smart-footwear ORPHE ONE

Authors: Naoyuki Hirasawa, Daichi Shimizu

Support: no new folk studio, Inc.

DanceAI automatically detects the movements of break dances and feeds back the results using smart-footwear ORPHE ONE. This system incorporates an AI (deep learning) that learns movements in natural environments using shoes with acceleration sensors (Fig.3). It can classify skills and steps and evaluate their proficiency using an application and the LED colors of the shoes.

Fig. 3. DanceAI × smart-footwear ORPHE ONE

2.4 Through the Looking-Glass

Authors: Antoine Pasquali, Corentin Risselin, Daniel Majonica, Javier Fdez, Steven Weigh
Support: Cross Compass, Ltd.

This exhibit lets viewers immerse themselves in bio-inspired deep learning mechanics in a dynamic and interactive way (Fig.4). The AI's task is to apply a multi-style transfer to the video feed in real time as a demonstration of creativity. Each screen acts as a different type of looking-glass. The left screen directly reflects what we see (the video feed) and perceive (convolutional layers) of the real world. The center screen shows the "Latent Space", which is an integration layer for all the signals that contribute to achieving the task – in this case, merging different styles of transfer. For the human brain, this is called "Connectome", a map of the neural wiring between various areas of the cortex. On the right screen, reconstruction layers (deconvolution) operate the multi-style transfer.

Fig. 4. Through the Looking-Glass

2.5 Visualization of Body Information using Color

This exhibit considers the possibility of making hidden information noticeable by visualizing body information using color. The following three works are on display.

2.5.1 Can Cloud AI Read Your Feelings?

Authors: Yousun Kang, Duk Shin

When viewers press the button in front of the small monitor (Fig.5, center), the camera on the large monitor sends data to a cloud AI, which recognizes their faces [2]. While the viewers' estimated ages and genders are output on the large monitor, if their emotions can be properly read from their facial expressions, LED lights output a color according to the emotion.

2.5.2 Visualization of Heart Rate with Color

Author: Takenori Obo

This system calculates heart rate from data acquired by the air pressure sensor installed on the chair and represents them in color using a LED tape (Fig.5, right).

2.5.3 Color Expression by Pole Movement

Authors: Keisuke Kojima, Hiroto Akiyama, Kihiro Kawahara, Daiki Tanaka, Masahiko Yamamoto, Masaomi Sanekata, Yuta Ogai

Accelerometer sensors attached to poles such as Nordic walking poles and bamboo swords measure the movement of the pole. An LED tape on each pole shows the movement by converting the data to a color (Fig.5, left).

Fig.5. Visualization of Body Information using Color

3. ASSOCIATED EVENTS

Kenichiro Mogi, a brain scientist, was invited to the opening of this exhibition at the Atsugi Campus of Tokyo Polytechnic University on Nov 30, 2019 to give a talk about the relationship between color and consciousness. In addition, on Dec 19, 2019, Naoaki Fujimoto was invited to present a special lecture on "How to Create Interactive Art". Their informative talks were well-attended and a valuable addition to the exhibition.

4. ACKNOWLEDGEMENT

This research was supported by the Private University Research Branding Project sponsored by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT).

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Real-Time Emotion Estimation System Using Face API of Microsoft Azure

Yousun Kang*, Takenori Obo*, Yuta Ogai, and Duk Shin****

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* Department of Applied Computer Science, Facility of Engineering
** Department of Electronics and Mechatronics, Facility of Engineering

ABSTRACT

This paper presents real-time emotion estimation system using the Face API of Microsoft Azure. The system can display the results of estimated emotion extracted from face image with color light. We introduce the Face API of Microsoft Azure which is a kind of cognitive service to identify and analyze content within images. Experimental results showed that the proposed system is effective for implementing an estimation of not only emotion but also age and gender in real-time.

1. INTRODUCTION

There will be more opportunities for communication between human and AI (Artificial Intelligence) using natural language. Emotional intelligence of computer systems is increasingly important in human-AI interactions. For example, a humanoid robot "Pepper" of SoftBank is the personal communication robot that can read emotions, with the ability to analyze people's expressions. Facial image holds important quantity of attributes and information about a person, such as facial expression, ethnicity, gender, and age. To predict emotions from facial expressions images, many methods are proposed in recent years. In this paper, we propose a new system to predict emotion from facial image in real-time. The system uses cloud computing platforms provided by Microsoft Azure. The results of the estimated emotion display text words in a monitor and show a color light in smart lighting system. In the next section, we introduce the cloud computing and Microsoft Azure. The proposed system is explained about configuration of hardware and software in section 3. Experimental results show in section 4. Finally, we conclude and summarize work in section 5.

2. FACE API OF MICROSOFT AZURE

2.1 Cloud Computing

Cloud computing platforms provide servers, storages, networking, applications over the Internet cloud with lower cost. There are some representative services such as AWS (Amazon Web Services), Microsoft Azure, and GCP (Google Cloud Platform). Since these commercial services give more secure, reliable and flexible platforms than on-premises servers, and more people are starting to use cloud computing services. The proposed system utilizes Microsoft Azure which can operate hybrid and seamless servers integrated into edge computing environments.

2.2 Azure API (Application Programming Interface)

Among various cloud computing platforms provided by Microsoft Azure, we applied Face API to the vision part of cognitive services. Face API can detect and compare human faces. In addition, Face API integrates emotion recognition, returning the confidence across a set of emotions for each face in the image, such as anger, contempt, disgust, fear, happiness, neutral, sadness and surprise. These emotions are understood to be communicated universally across cultures with particular facial expressions.

3. SYSTEM CONFIGURATION

3.1 Hardware Setup

The system comprises a web camera as an input device, a PC based Window 10, a 60-inch monitor as a display, and color lights Hue in Philips as an output device. Hue in Philips is a smart lighting system with a bridge. The bridge acts as a smart hub, connecting with our PC to output color light. Fig. 1 shows the appearance of the system in the cololab gallery in Tokyo Polytechnic University. To implement the system, the user has to put a switch called the action button as shown in Fig. 2. We prepared another monitor displaying the manual about the usage of the system with the action button.

Fig. 1 The appearance of the proposed system in the gallery of cololab

3.2 Application Program

The application program is compiled by Python. By using the specified threshold value, we can estimate an emotion among the various trained data by deep learning model. We can display the results to text words in the monitor and the size of the text represents the estimation performance. Bigger text means higher performance. When the application is executed in real-time, all results are back up in the system.

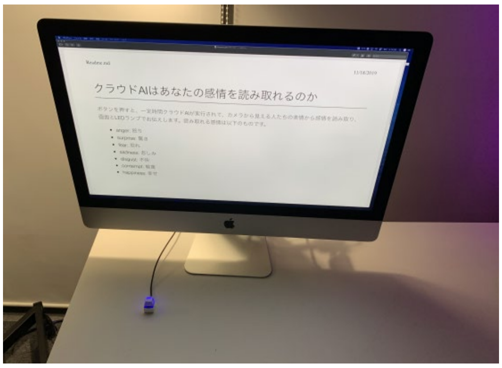


Fig. 2 Display of the manual about the usage of the system with the action button of the other monitor

4. EXPERIMENTAL RESULTS

In this section, we show the results of the proposed system. Fig. 3 shows the sample images of a display for emotion estimation, age, gender. The application program is able to recognize faces from many people. Therefore, recognized faces are simultaneously shown in the display monitor. In addition, the smart color light system shows the result from a person shown in Fig. 4. The smart lighting system has the color of the rainbow such as red, orange, yellow, green, blue, indigo, and violet. Each color corresponds with the estimated emotion as shown in Table 1.

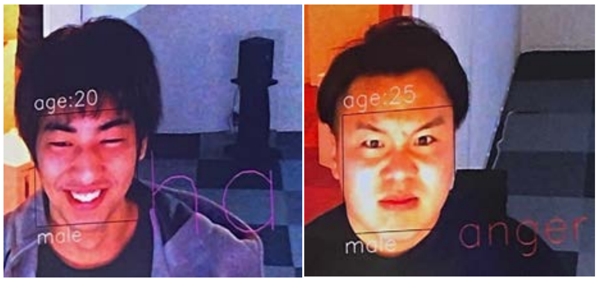
5. CONCLUSION

In this paper, we estimated emotion, age, and gender extracted from facial image in real-time. The system can display the color of light according to the emotion results with the Face API of Microsoft Azure. The relation of color and emotion should be investigated in psychological effects for future work. Since colors and emotions are closely linked, we can develop the communication system using colors psychology and smart lighting system.

Table1 Corresponding color lights from the estimated emotion

Colors lights	Estimated emotion
Red light	Anger
Orange light	Surprise
Yellow light	Fear
Green light	Sadness
Blue light	Disgust
Indigo light	Contempt
Violet light	Happiness

(a) sadness (b) disgust



(c) happiness (d) anger

Fig. 3 Results of estimated emotion in display monitor

(a) red light (b) orange light

(a) green light (b) violet light

Fig. 4 Results of various color light system according to estimated emotion

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Comparative Analysis on the Effect of Illumination Color in Clinical Environment of Preventive Care

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ABSTRACT

Conventional lights used in house were only white and the industrial standard that has recommended the optimal usage of lights have based on the color temperature. Illumination used in daily life these days has extended to provide the capability of using full color lights thanks to recent progress of LED lighting technology, but the standard mentioned above has not considered the effect of color lights on humans yet. Here we investigated the effect of colored lighting conditions on human cognitive performance by conducting an experiment where the subjects from multiple elderly generations executed cognitive tasks under several specific illumination conditions with color to see how the task score and their biological responses would vary among the conditions.

1. INTRODUCTION

Humans have nature for adopting to their environment and keeping social balance with others by using all their senses, *i.e.*, vision, auditory, olfactory, gustatory, and tactile. From a different point of view, the environment including other people that surround a person may change the way of affecting him or her so that he or she could enhance the ability for doing tasks. Cheering in a sport event is one of the examples where the audience plays the role of surrounding environment of a sport player that could empower him or her by sending cheers. So is the case in the working environment where intellectual performance is required except for physical one.

Recent progress in lighting technology using LED has enabled to use full color lights in daily life. However, no scientific evidences support what color lighting stimuli could be another cheering environmental factor because conventional room lights were only white with a variety of color temperatures and industrial standards for lighting have all based on them [1]. Not only houses but also workplaces these days pay much attention to the environmental conditions so that to maximize the performance of workers in them by improving the quality of their lives, which is critical under the circumstances of shortage of workers in Japan.

In this paper, we report an experimental result where the subjects executed cognitive tasks under a specific set of colored illuminations to see how they affect the task score and the biological responses of humans.

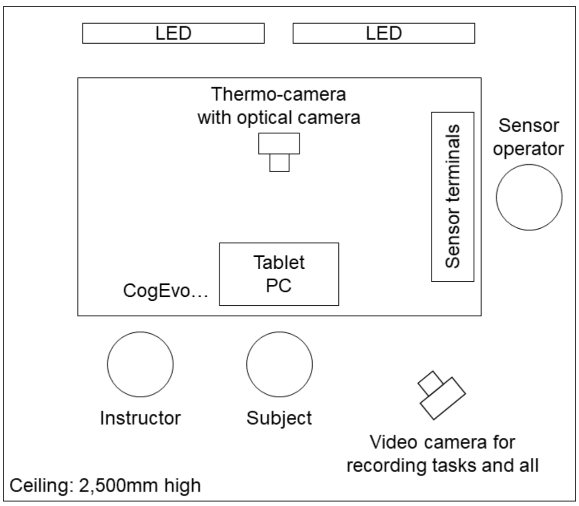


Fig. 1 Experiment room

2. EXPERIMENTS

2.1 Cognitive tasks

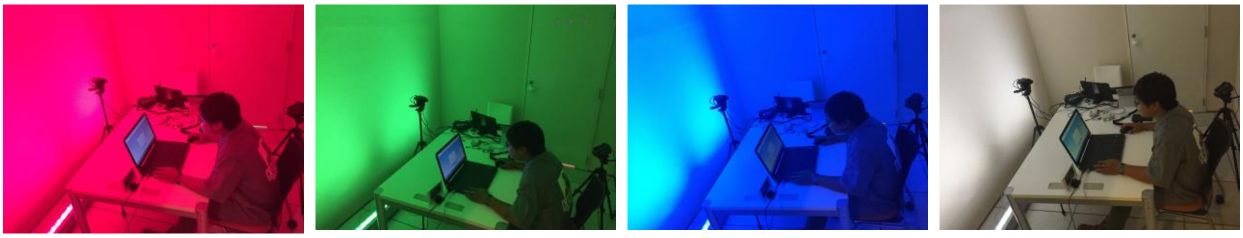
We exploited *CogEvo* that is widely used in research institutes as, so to speak, *de facto* standard [2]. It divides a measurement task for cognitive performance into five categories, 1) spatial awareness, 2) orientation, 3) memory, 4) attention, and 5) planning. Every task is a kind of game and takes fifteen to twenty minutes in total to finish.

2.2 Subjects

Three elderly generations across fifties to seventies with twelve subjects (six for both males and females) were instructed to do the task explained in Section 2.1. They are healthy and cognitively clear. They understand the experiment and the task and are able to do the task without any accidental mistakes.

2.3 Experiment room and illumination conditions

Fig.1 shows the experiment room where the subject sits next to the instructor who teaches the subject how to do every task. A camera system that has thermos-camera and optical camera stuck together locates in front of the subject, and another video camera diagonally behind the



(a) red (b) green (c) blue (d) white

Fig. 2 Color conditions for calculation task.

subject that takes the scene of doing tasks and all. The subject puts on heart beat sensor (myBeat [3]) at the beginning.

Two LED lights locates under the wall facing the subject that illuminate the whole wall and the ceiling over the wall, which is the entire view of the subject in other words. The illumination of every color was set to the maximum illumination of red. Each subject did the task under a single illumination condition assigned.

2.4 Measurements

The thermo-camera captures the temperature of the skin around root nose that correlates with the concentration (the optical camera detects face region and facial components from the image). The heartbeat sensor captures heartbeat wave whose specific frequency components correlate with nerve activities [4]. Also, the optical camera gives the number and the timing of eye-blinking that is known to be an indicator of memory process in brain activity [5][6].

Those measurements were later analyzed with respect to the age, the task score, and the illumination conditions where three subjects for each generation (fifties, sixties, and seventies) conducted the task under the same illumination condition.

2.5 Results

As the subjects got older, the score for every task got worse just as anticipated. Illumination condition did not affect fifties and seventies in every cognitive task. Only in sixties, a significant difference was found in the planning task (see Fig.3). The score under blue lighting condition topped those in green and white with 1% and 5% significance level respectively. Blue light would enhance the ability of planning (planning ability decreased in seventies compared with fifties and sixties).

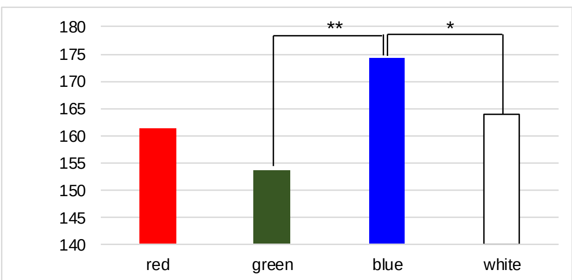


Fig. 3 Comparison of task scores between illumination conditions (Planning for sixties).

Blinking rate counted the highest number in seventies. In addition, it counted higher in red light compared with green and blue when significantly different (spatial awareness for fifties and sixties, and memory for fifties). Red light might have forced difficulty in memorization and getting aware of space.

4. CONCLUSION AND FUTURE WORK

We conducted an experiment that varied illumination colors when subjects did cognition tasks. The task scores correlated with the age, the biological metrics of heartbeat rate and eye-blinking rate, and the illumination colors. The result demonstrated that planning task for sixties enhances under blue light. In addition, red light seemed to give load to cognitive task that led to higher rate of eye blinking.

Future work include extending the experiment to cognitive performance in younger generation and also human communication that could be affected by colored illumination.

Acknowledgement

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Butterfly Color Vision - Another View of Our World

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ABSTRACT

Butterflies often feed on nectar of colorful flowers. How do they find flowers? Do they discriminate flowers by color? We found a swallowtail butterfly uses sophisticated color vision when searching for food. Surprisingly, color vision system appears to be very much different among animals, even among butterflies. I will overview the current understanding of insect color vision from the evolutionary point of view: each animal has its own visual world. Study of insect vision should also contribute designing novel "visual" devices and to manage insect pests for the crop without using chemical insecticides.

1. INTRODUCTION

Color vision is the ability of discriminating visual stimuli based on their spectral (wavelength) contents irrespective of the intensity. We have a trichromatic system based on the blue (B), green (G) and red (R) light sensitive sensors (photoreceptor cells) in the eye (Fig. 1A). Color vision appears to be rather common among animals, some of which in fact exhibit surprisingly good performance in discriminating colors. For example, a swallowtail butterfly *Papilio xuthus* can detect only 1 nm difference in wavelength, which rivals our performance. But *Papilio*'s performance is even better because their visible light expands deeply into the ultraviolet range that we cannot see. We now know that *Papilio* has a tetrachromatic system based on the UV, B, G and R sensitive photoreceptor cells in the compound eye. We have also demonstrated that *Papilio* exhibits color constancy and simultaneous color as well as brightness contrast. Here I first summarize our current understanding about the color vision mechanism of *Papilio*, and then will compare color vision among animals.

2. COMPOUND EYES

2.1 Photoreceptor spectral sensitivities

Compound eyes are composed of multiple units called ommatidia. The ommatidial array is visible from outside as a number of hexagonally-packed facets. The diameter of a facet is about 25 µm in most insects, which makes the number of ommatidia roughly proportional to the size of compound eyes. An ommatidium is a long structure, which are tightly packed to each other making the compound eye a dome-shaped structure. A compound eye of *Papilio xuthus* is made up with about 12,000 ommatidia.

An ommatidium of *Papilio* contains nine photoreceptor cells. Each photoreceptor bears numerous microvilli containing photosensitive protein, rhodopsin, forming a single rhabdom along the ommatidial longitudinal axis. The rhabdom is surrounded by red or yellow pigment, which act as spectral filters for the photoreceptors. A subset of red-pigmented ommatidia has UV-absorbing fluorescence pigment at the top of the rhabdom. Distribution of the red, yellow and fluorescing ommatidia appears random: the *Papilio* eye is a random mesh of 3 types of ommatidia.

Spectral properties of rhodopsin and the filter pigments determine photoreceptors' spectral sensitivity, which can be determined by measuring electrical responses of them. We thus identified UV, violet (V), B, G, R and broad-band (BB) receptors (Fig. 1B). The receptors are embedded in 3 types of ommatidia in 3 fixed combinations [1]. The spectral heterogeneity of butterfly eyes is a particularly pronounced case among insects [2].

3. COLOR VISION OF *PAPILIO*

3.1 Color vision with color constancy

To demonstrate color vision in *Papilio*, we trained naïve *Papilio* to take nectar on a colored disk, simulating their flower-visiting behavior in the field (Fig. 1D). *Papilio* readily becomes able to visit the colored disk even if it is presented with disks of other colors. *Papilio* really used chromatic cue of the disk, not the brightness, because they could select the colored disk among the disks of different shades of greys.

Perceived colors of objects basically remain constant irrespective of spectral contents of the illumination. This property is known as color constancy, which is important for animals that assess object quality by color. We confirmed that *Papilio* has color constancy by testing them under differently colored illuminations [3].

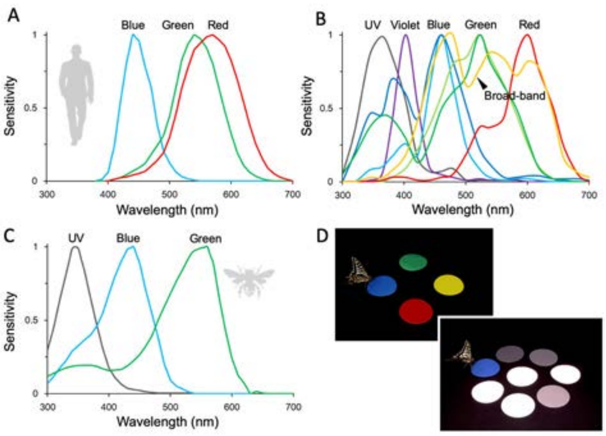

Fig. 1: Photoreceptor spectral sensitivities of humans (A), the Japanese yellow swallowtail, *Papilio xuthus* (B), and honeybee *Apis mellifera* (C). D) Color vision test in *Papilio xuthus*.

3.2 Wavelength discrimination

Dimension of color vision (tri- or tetra-chromacy, etc) can be studied by measuring wavelength discrimination ability. We can discriminate about 1 nm difference ($\Delta\lambda \doteqdot 1$ nm) in two wavelength regions, which are around 500 nm and 600 nm (see Fig. 2B). These regions respectively correspond to where the sensitivities of B and G receptors, and G and R receptors overlap. Existence of two highly sensitive wavelength regions is because the system is trichromatic.

We measured wavelength discrimination in *Papilio* using its feeding response. We trained butterflies to extend their coiled mouth towards light of certain wavelength. When shown the training light with another light of different wavelength at the same intensity, the butterfly extends its mouth towards the training light if two lights are discriminable. We thus found that *Papilio* can detect 1-2 nm difference at around 430, 480 and 560 nm, indicating that their color vision system is tetrachromatic. Model calculation well reproduced the behavioral results when we assumed the UV, B, G and R receptors contribute the discrimination (Fig. 2A).

Figure 2B shows the wavelength discrimination of some animals including humans. Honeybees and humans are trichromatic, while goldfish and *Papilio* are tetrachromatic. *Papilio*'s performance is indeed the best among them [4].

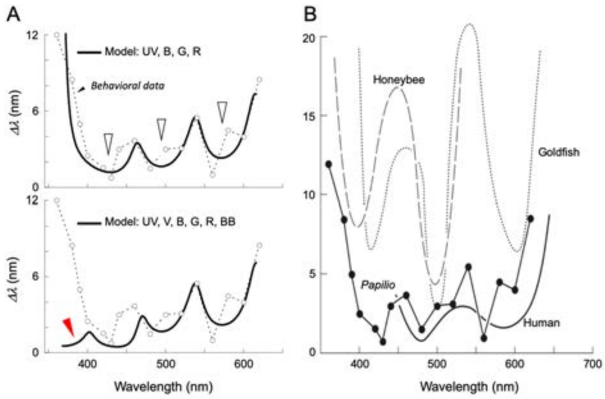

Fig. 2: (A) Wavelength discrimination (Δλ) function of *Papilio.* Troughs (open arrowheads) indicate high-sensitive regions. Behavioral data (dotted line) are well explained by the model with inputs from UV, B, G and R receptors (upper), but not by all six receptors (lower), where significant deviation is observed in the UV region (red arrowhead). (B) Comparison of wavelength discrimination of animals.

4. COMPARATIVE ASPECTS

4.1 Photoreceptor diversity

As shown in Figs 1C and 2B, color vision of honeybees and butterflies are different. Even among butterflies, color vision properties appear to be different. Because behavioral experiments are not easy to perform, this has not been convincingly demonstrated at the behavioral level. However, we see a clue of the variability at the photoreceptor level.

Some butterflies have only 3 receptor classes (UV, B and G) in their eyes as honeybees do, suggesting their trichromacy. Some have 6 or more. The cabbage white, *Pieris rapae*, has 6 as in *Papilio*, but the sensitivity profiles are different: they are UV, V, B, G, R and dark red. In addition, the V receptors are found only in females. They are replaced by double-peaked B (dB) receptors in males. Sexual dimorphism is even more pronounced in the Eastern pale clouded yellow, *Colias erate*, where males have one class of R receptors, while females have 3 classes of them. Multiple R receptors would make females capable of discriminating subtle differences in greenish, yellowish, and reddish colors. This is probably beneficial in assessing quality of leaves on which to lay eggs [5].

In terms of the number of receptor classes in butterflies, the Common bluebottle, *Graphium sarpedon*, has the record at this stage, which is 15 [6]. How does *Graphium* use these 15 classes of receptors? It seems unlikely that they are "pentadeca-" chromatic. *Papilio* uses 4 out of 6 for color vision. If this is also the case of *Graphium*, other 11 receptors may be useful for detecting specific stimuli, for example, fast-moving objects against the sky, or particular light wavelengths reflected from potential mates or enemies.

4.2 Perspectives

We of course cannot see the world as butterflies do, because our eyes and brains are designed differently. It is however still exciting to try to understand how the world of butterflies looks like by combining evidence from various kinds of experiments. We are currently studying hard to understand how the wavelength information is processed in their tiny brains to produce "colors" as their own experience. We are also interested in how color vision systems have evolved over time by comparing the eyes and brains of many different insects.

In this process, we may even discover principles for designing new artificial "visual" systems. It would be fantastic if we could program drones to use their "eyes" to control themselves as skillfully as insects do. Another possible application of insect vision research is to control insect pests. Excess use of chemical insecticides damages environment. Perhaps we can safely keep pest insects away from crops by using light instead of chemicals. For this, we first have to understand how insect visual systems work.

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AI Photographer Generating Experimental Photographs Using Artistic Style Transfer Neural Networks

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ABSTRACT

Contemporary photographers have the idea of conflating the imaging possibilities of digital technologies with an experimental spirit. The AI photographer developed in this project can produce experimental photographs using deep learning, by which the methods of a human contemporary photographer are learned by artistic style transfer neural networks. The AI photographer generated thousands of diverse mutations of a photograph as if forming a new generation that builds the future as the descendants of a few pairs of parents.

1. BACKGROUND

Rainbow Variations by the photographer T. Koyama weaves together *Rainbow Forms*, *Melting Rainbow*, *Waves Rainbow*, *Seventh Depths*, and *Pico*[1]. Each dazzling distortion was rendered using a layered, manual process. For example, the camera captures the water droplets and reticulations of the wet photographs, the changing wave patterns of submerged photographs in clear water, intentional mistakes using a multi-shot digital camera, etc.

In collaboration with T. Koyama, I have developed an AI system that learns a method of producing experimental photographs using artistic style transfer neural networks. First, the works named *Rainbow Variations: AI mutations* displayed at the fourth Special Exhibition at the Color Science and Art Center, known as the “Collab Gallery,” is inspired by *Rainbow Variations*. Second, using this experience, the works named *AI Photographer Rainbow Mutations* can create further unexpected mutations using additional distortion data. These works were exhibited at Tokyo Polytechnic University's Festa in the Faculty of Art 2019.

2. WORKS

2.1 *Rainbow Variations: AI mutations*

Rainbow Variations: AI mutations generated experimental photographs through inspiration by the concept of *Rainbow Variations* using the interactive artforms *AI Artistic Painting Mirror*[2] and *Deep Neuro Artist*[3], which are based on deep neural networks. In the exhibition, a video installation showed 1044 reconstructed photographs. AI learned three distortion data of *Meltings, Waves,* and *Seventh Depths* as a style image (see Figures 3, 4, and 5) and generated new mutations from *Rainbow Forms* as a contents image (see Figure 2). This video installation was exhibited as a 55-inch portrait-style OLED display panel. (See the left-hand image in Figure 1.)

2.2 *AI Photographer Rainbow Mutations*

AI Photographer Rainbow Mutations expanded *AI mutations* to generate further complex mutations[4]. In addition to the distortion data of the previous exhibition, many types of data have been superimposed and crossed over to produce 3414 novel mutations. For example, AI learned *Bubbles, Waves Rainbow*, and the experimental photos by Hajek Halke who is a German experimental photographer (see Figures 6, 7, and 8). Additionally, AI learning was also executed under the condition of swapping a style image for a contents image. Examples of generated photographs are shown in Figure 9. This video installation was exhibited as a 65-inch landscape-style OLED display panel[4]. (See the right-hand image in Figure 1.)

3. PERSPECTIVE

In this collaboration, we have generated experimental photographs using neural networks that learned the process of producing of a photographer. We can recognize the potential of AI learning the processes of thinking and producing of artists. Neural networks will be able to learn various styles of artistic processes in the future.

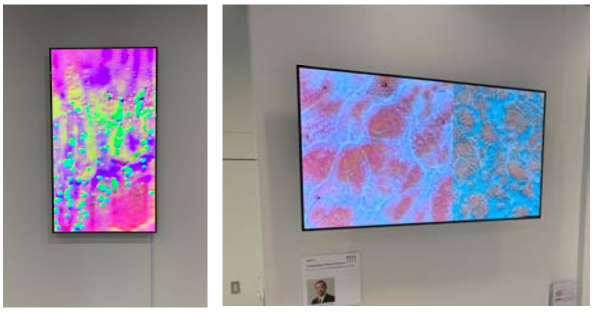

Fig. 1 *Rainbow Mutations* Exhibition.

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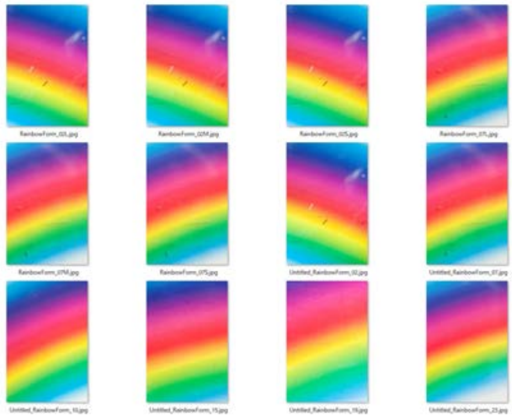

Fig. 2 ***Rainbow Forms*** **12.**

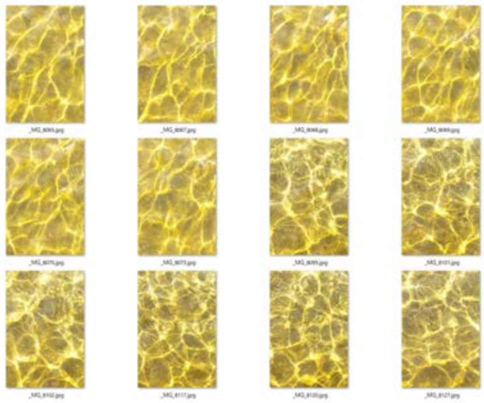

Fig. 3 ***Waves*** **12.**

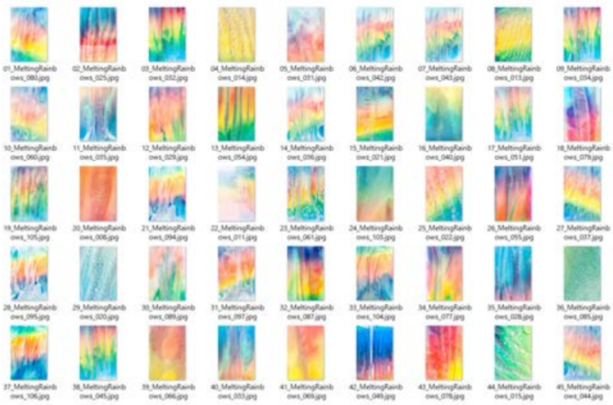

Fig. 4 ***Meltings*** **45.**

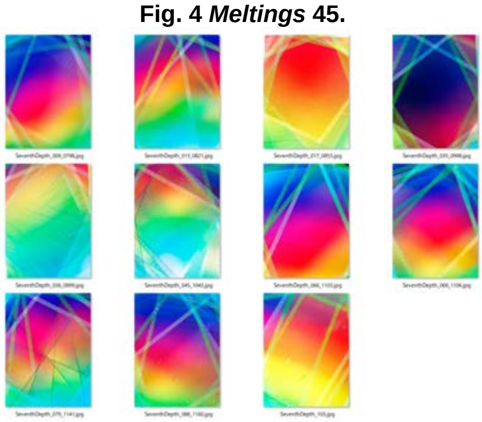

Fig. 5 ***Seventh Depths*** **11.**

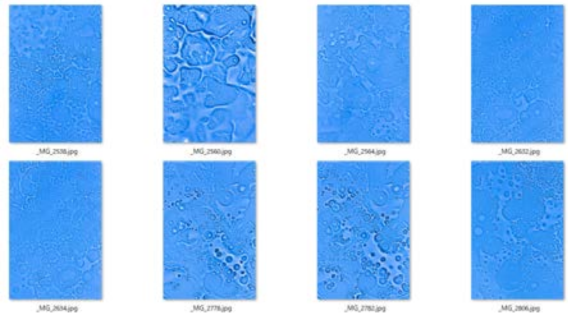

Fig. 6 ***Bubbles*** **8.**

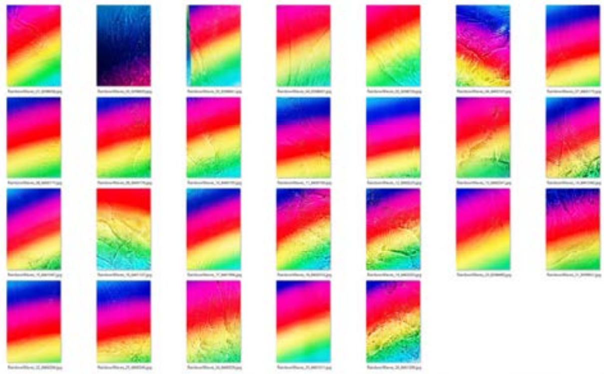

Fig. 7 ***Waves Rainbow*** **26.**

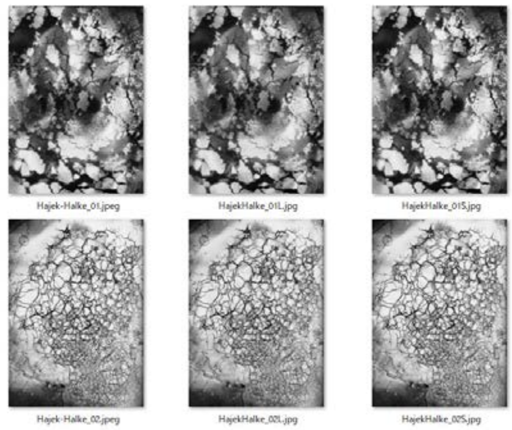

Fig. 8 Photographs by Hajek Halke 6.

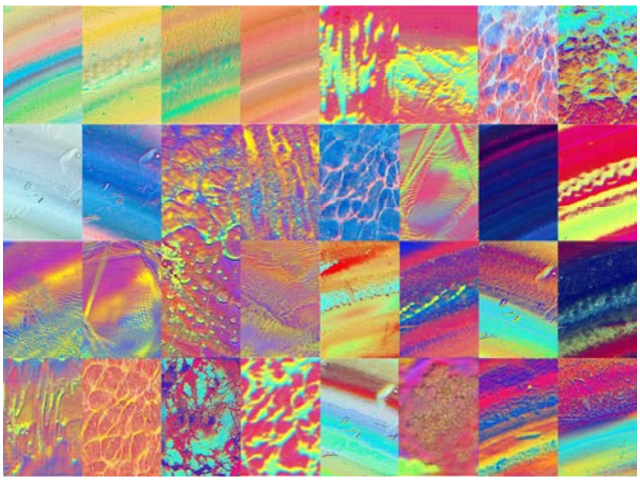

Fig. 9 Examples of ***AI Mutations***

A Fundamental Study on the Effect of Pigment Use Amount on the Color of Colored Mortar

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ABSTRACT

Focusing on the mortar portion, which is considered to determine the color of concrete, experimental verification was conducted on the effect of the amount of pigment used on the color of colored mortar. In the preliminary experiment, the color of the mixed powder of cement and pigment constituting the cement paste appearing on the surface layer of the mortar was measured. As a result, it was found that the region in which the color of the mixed powder effectively changes as the pigment substitution rate increases or decreases is in the range where the pigment substitution rate relative to the cement mass is lower than 5% to 10%. Further, in the range where the pigment substitution rate relative to the cement mass is lower than 5%, a clear change appears in the L*a*b* values of the mortar as the pigment use amount is increased or decreased. As the pigment substitution rate increased, the L* value decreased and the a*b* value approached the pigment color. However, since mortar with the low pigment substitution rate of 1.25% can be clearly confirmed visually to be blue, green, or yellow, relatively inexpensive colored mortar is considered to be usable, taking into account the optimum use method, including the factor of cost.

1. INTRODUCTION

Colored concrete colored with pigments is used for building exterior walls and floor slabs. The amount of pigment added to such concrete is often based on the standard addition amount specified by the pigment manufacturer. However, a wide variety of materials and blends are used for concrete, and the dosage of pigment is adjusted as required. When determining the dosage of pigment, factors such as the water-cement ratio of concrete and color change over time must be taken into account, but there are very few research reports on such systematic experiments. In the present study, focusing on the mortar portion, which is considered to determine the color of concrete, experimental verification was conducted on the effect of the amount of pigment used on the color of colored mortar.

2. Preliminary experiment with mixed powder

Prior to the main experiment, a preliminary verification experiment was conducted regarding the color of the mixed powder of cement and pigment constituting the cement paste that appears on the surface layer of the mortar. Photo 1 shows a picture of the experiment. In the

Photo 1 Experiment on the effect of pigment substitution rate on cement color

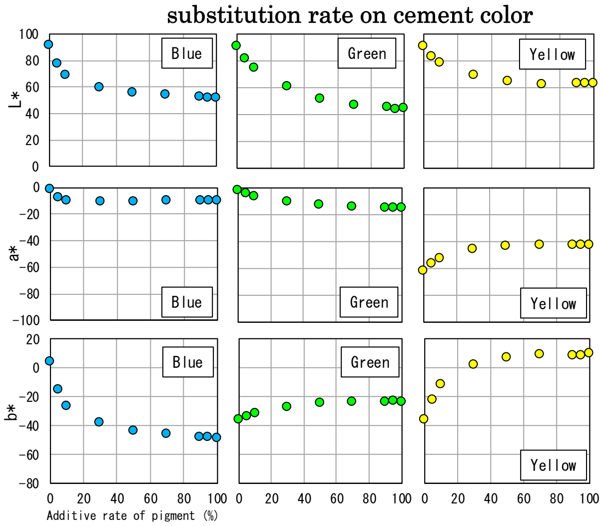


Fig. 1 Relationship between pigment substitution rate and L*a*b* values of mixed powder

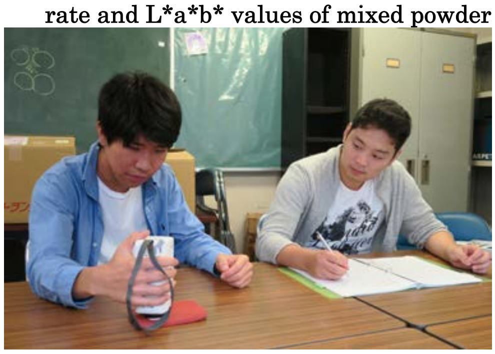


Photo2 Color Measurement of Colored mortar

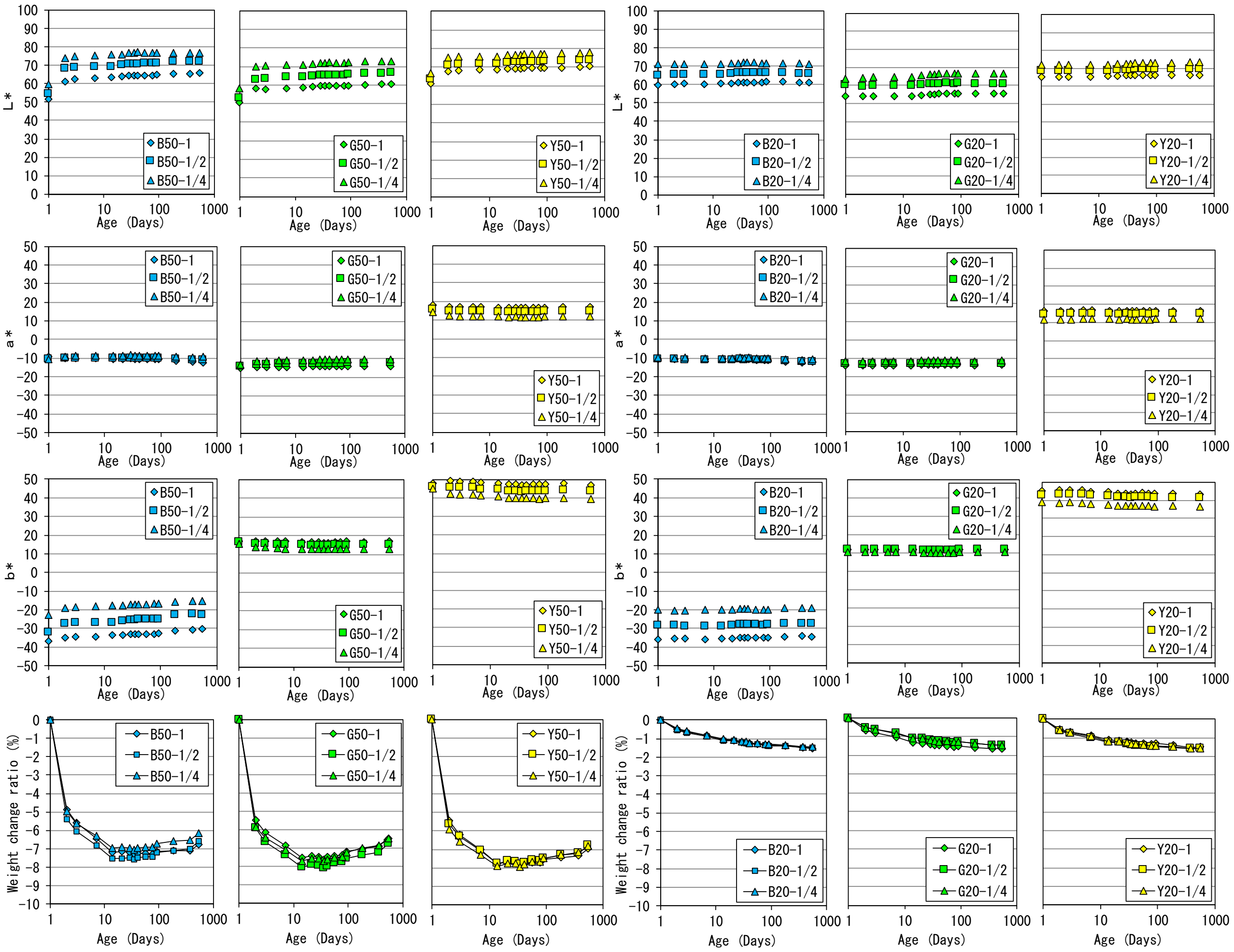
experiment, powders in which blue, green, or yellow pigment was mixed with white portland cement at a substitution rate of 0% to 100% were manufactured, and the L*a*b* values of the mixed powders were measured. The experiment's results are shown in Fig. 1. Similarly, to past findings in other fields, the influence of the pigment substitution rate on the color of the basic powder (cement) becomes milder as the pigment substitution rate increases. Looking solely at the L*a*b* values of the mixed powders, the region in which the color of the mixed powder effectively changes as the pigment substitution rate increases or decreases was considered to be in the range where the pigment substitution rate relative to the cement mass is lower than 5% to 10%.

3. Mortar experiment

The color measurement results are shown in Fig. 2. Further, in the range where the pigment substitution rate relative to the cement mass is not over than 5%, a clear change appeared in the L*a*b* values of the mortar as the pigment dosage was increased or decreased. As the pigment substitution rate increased, the L value decreased and the a*b* value approached the pigment color. Moreover, although color change over time occurred in the mortars with the water-cement ratio of 50%, the differences in Lab values due to the different substitution rates were not narrowed.

4. CONCLUSIONS

1) The region in which the color of the mixed powder effectively changes as the pigment substitution rate increases or decreases was considered to be in the range where the pigment substitution rate relative to the cement mass is lower than 5% to 10%.
2) In the range where the pigment substitution rate relative to the cement mass is not over than 5%, a clear change appeared in the L*a*b* values of the mortar as the pigment dosage was increased or decreased.



(Blue specimen) (Green specimen) (Yellow specimen) (Blue specimen) (Green specimen) (Yellow specimen)

W/B=0.5 W/B=0.2

Fig.2 Measurement results of L*a*b* value and weight change ratio

Development of Structural Color Material Contributing to Maintenance Management of Social Infrastructure and its Application in the Civil Engineering and Architecture Fields.

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ABSTRACT

This project constitute of the two independent themes related with the structural color materials. (1) The one is to develop the structural color materials detecting the aging degradation of building material as the change of color. (2) The other one is to develop the educational tool made it possible to visualize and colorize the sounds. At first, we succeeded in directly applying a structural color pigment on the rough surface of concrete without primer coating. Secondary, we demonstrate the visualization and colorization of Chladni patterns created by the structural color materials.

1. INTRODUCTION

Structural colors are responsible for many of the brilliant colors we see in nature. The blue of the sky, the rainbow of colors in an oil slick, the bright colors of peacock feathers, the brilliant blue of a Blue Morpho butterfly, the metallic colors of certain beetles, and the glimmering colors of some fish, are all due to structural color. This project constitute of the two independent themes related with the structural color materials. (1) The one is to develop the structural color materials detecting the aging degradation of building material as the change of color. (2) The other one is to develop the educational tool made it possible to visualize and colorize the sounds.

I. Development of Structural Color Material Contributing to Maintenance Management of Social Infrastructure and its Application in the Civil Engineering and Architecture Fields.

1 Introduction

A fifty or more years has passed since the last Tokyo Olympics. Most of the social infrastructures built at that time are rapidly progressing their deterioration. It is very important issues in Japan to construct the maintenance systems for easily diagnosing the deterioration of social infrastructures. We focus on the point that the structural color materials exhibit the remarkably change of colors by the structural damage and distortion, which cause with applying a slight external stimulus such as pressure, temperature and vibration. In this study, we tried to develop the structural color paint to diagnose the aging deterioration of buildings as the change of color.

2. Experimental

The structural color pigments (SCP) were obtained from Toyo Aluminiums K. K., called “Chromashine”. The silicon, urethane and epoxy resins was used as the main ingredient. The weight ratios of pigment and synthetic resin were 1:10 and 1:20. In this project, the structural color paints were directly applied to the concrete surface without using additives or primers.

3. Results and Discussion

As show in Figure 1, all of pigment exhibit to retain the clear metallic color despite the roughness of concrete surface, and their color change depending on the view angle. Urethane and silicon resins could be successfully applied the pigment n the concrete surface, whereas the epoxy resin was repelled on the concrete surface, causing the color unevenness.

Figure 2 shows the typical reflectance spectra of SCP applied on the surface of concrete. The absorption bands were observed at the identical wavelength regardless of the differences of the resin. However, the maximum reflectivity strongly depends on the resins, increasing in order of urethane > silicon > epoxy resins.

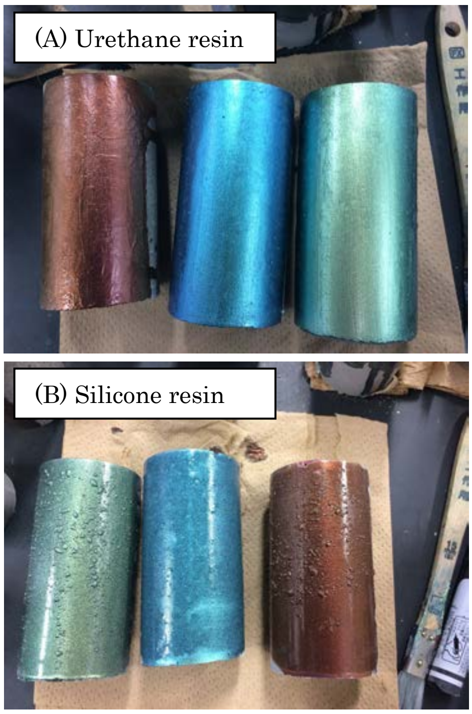

Figure 1. Photographs of SCPs on the concrete surfaces, (A) Urethane and (B) Silicon resins.

In particular, it should be noted that the silicon resin retain the high transparency, indicating to be a candidate for the transparent dispersant in Section II.

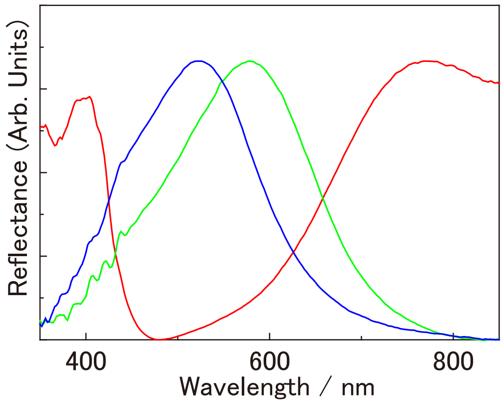

Fig. 2 Typical reflectance spectra of the SCP-urethane paint applying on the concrete surface.

Figure 3 shows the comparison of colors of SCP-urethane paints before and after destruction of concrete. Unfortunately, we could not observed the color change of pigments with generating the cracks on the concrete.

II Development for Coloring of the Mysterious Geometric Pattern "Chladni Figure" Made by Sound with Using the Structural Color Materials

1. Introduction

Structural color is one of the interference of light; it arises through the reflection of light from complex nanostructures found in the feathers of birds or the hard outer shell of beetles. These multi-layered structures produce iridescence, whereby the color appears to change depending on the angle of view. In contrast, Chladni figures are one of the resonance phenomena of sounds; it reveals the various shapes or patterns characteristic of the vibrational mode of sounds, as shown in Figure 4.

If we can make Chladni figures colorized by using the structural color materials, it could be an extremely effective educational tool not only in experiencing scientific interest but also on understanding in both of the interference of light and the resonance of sounds for Japanese high school students. In this study, we wish to demonstrate the Chladni figures changing optical patterns according to the frequency of sound and the angle of view.

Figure 4. Chladni figures in the various frequencies [1].

2. Experimental

The sand art powder were obtained from Koeido Hobby Ltd. SCP was also used “Chromaschine®”. Silicon oil (350 cp) was used as the dispersion matrix for the SCP. The weight ratios of SCP and silicon oil were 1:20. Chladni figures were drawn on the iron plate equipped with the vibration generator and function generator.

3. Result and Discussion

As shown in Fig. 5, we succeeded in drawing the color-coded Chladni figures by using the difference of density of the sand art powder.

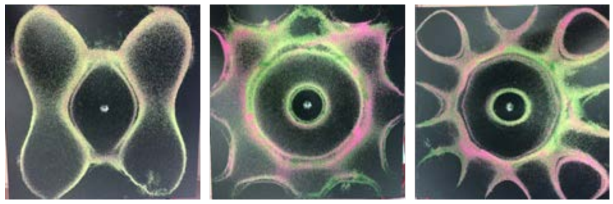

Figure 5. Photographs of Chladni figures drawn by using the sand art powders.

Applying the vibration to SCP dispersed in Silicon oil, we found to change the color tone of the optical texture with elevating the frequency, although it is not necessarily so clear (See Figure 6). In order to draw the clearer optical texture, it would be necessary to optimize the viscosity of silicone oil and concentration of SCP.

Figure 6. The variation of optical texture of SCP dispersed in Silicon oil as a function of the vibrational frequency.

4. REFERENCES

https://dailynewsagency.com/2013/06/10/amazing-resonance-experiment-g7j/

Figure 3. Comparison of colors in SCP-urethane paint before and after destruction of concrete.

Color Planning in Modern Architecture: Focusing on Housing Estates in Germany during the Weimar Period

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ABSTRACT

Modern architects developed color planning during the period of Germany's history known as the Weimar Republic. This study discusses its use in modern architecture by focusing on the Britz housing estate, designed by Bruno Taut in the second half of the 1920s in Berlin. This housing estate consists of three-story apartment houses and two-story townhouses, each of which has different color-planning characteristics. The author tries to clarify them by analyzing an architectural model made with the help of a field study and concludes that Taut's approach to color planning seemed to change within a short period of time.

1. INTRODUCTION

Modern architecture that appeared at the beginning of the twentieth century in Europe realized geometry-based, abstract architectural design. As we know these works mainly from black-and-white photographs, we may believe that modern architecture was largely white and without color. However, various colors were used to enrich architectural spaces; in fact, color was one of the most important elements of architecture at that time. Many architects dealt with this in Germany during the Weimar Republic, especially in the great numbers of housing estates built in this era, where various colors were used both on the inside and the outside of buildings. One of the most famous German architects in this period was Bruno Taut (1880-1938). This paper focuses on Taut's masterpiece, the Britz housing estate, and considers his approach to color planning by analyzing an architectural model made with the help of a field study.

2. Bruno Taut and Housing Estates in Berlin

In the history of modern architecture, Bruno Taut is famous as an expressionist architect who presented an original utopian vision in approximately 1920 as well as being known for his work in Japan during the 1930s. However, he was most productive during the Weimar Republic, especially in the second half of the 1920s. As the chief architect of a housing company named GEHAG, he planned almost ten thousand dwellings in Berlin from 1924 to 1931. After World War I, Germany faced a serious housing shortage, and many reasonable dwellings were required. For that reason, many apartment houses were planned as simple buildings in which Taut used colors to enrich the inhabitants' living environment.

As some previous studies suggest[1], Taut's manner of architectural coloring gradually changed from the 1910s to the 1930s. In an early project called Garden City Falkenberg (1913-16), which was termed a "box of watercolors" at the time, he seemed to use colors freely, while the fifth section of a forest housing estate, Uncle Tom's Cabin (1930), shows a clear regularity in coloration. In the latter project, different colors were adopted according to the facing of the wall, i.e., he used green for the east walls and red for the west walls of houses because each color corresponded to the rising or setting sun.[2]

The Britz housing estate was designed between these two projects. As Taut did not give any concrete explanation about the color planning of this endeavor, we must consider his concept by analyzing the existing architecture. Berlin architects Helge Pitze and Winfried Brenne researched this housing estate in the 1980s, and most of its original colors have been restored in recent years. By referring to the documents written by Pitze and Brenne[3], and by constructing an original model of the housing estate, the author of this paper tried to understand Taut's concept. A study using an architectural model has the following merits: First, it allows the author to have a bird's-eye view of whole design, even a large project like a housing estate, and second, it means the author can see the colors of both the street- and garden-side walls, which are hard to observe on-site.

3. The Britz Housing Estate and its Architectural Model

Taut's Britz housing estate was constructed by GEHAG in six sections between 1925 and 1930, and this study focuses on sections one and two (1925-27), which are characterized by a central horseshoe-shaped building (Figs. 1, 2). These two sections consist of 555 apartments (one-story dwelling units) and 472 townhouses. The horseshoe-shaped building and the three-story buildings constructed along the peripheral roads were all planned to house apartments and were designed with flat-roofed, geometrical modern forms (Figs. 2, 3). The two-story townhouses located inside the site have seemingly traditional architectural forms with pitched roofs (Fig. 4).

The architectural model for this study was constructed with a scale of one to five hundred (1/500). Both the form and color of the houses were based on the documents written by Pitze and Brenne as well as observations made during the author's field study. The model was built of Styrofoam and colored with acrylic paints.

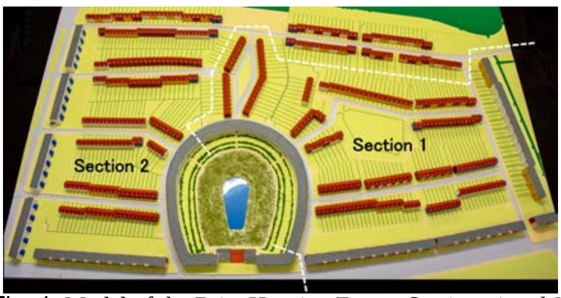

Fig. 1 Model of the Britz Housing Estate, Sections 1 and 2

4. Analysis of Taut's Color Planning in Britz

The color planning of the Britz housing estate shows the different characteristics of the three-story apartment buildings and the two-story townhouses. The former buildings have an eye-catching, unified coloration, as is seen on the horseshoe-shaped building (Fig. 2) or the red buildings (called Red Front) along the eastern peripheral road (Fig. 3). While planning these, Taut seemes to have wanted to create a contrasting color effect. For example, on the wall of the horseshoe-shaped building, Taut adopted white as the background color and emphasized staircases and the top floor with blue lines. The Red Front also has a contrast between its red background and pink staircases.

On the other hand, the townhouses show a relatively random coloration consisting of four colors: dark red, yellow, white, and blue. Each townhouse has one color on the street-side wall, and some of the townhouses have the same color on the garden side as that of the street side, while others have a different one. In a previous article[4], the author pointed out the following characteristics of colors on the street-side walls of these townhouses:

- Taut used dark red most commonly as a fundamental color. The number of blue residences was small, and they were mainly located at the end of a building.
- He gave the townhouses arbitrary zigzag arrangements and changed colors where the houses followed this layout.
- He varied coloration from street to street. For example, in some buildings, two colors alternated between every residence (or every two residences), while some buildings were unicolored.

The author concluded that because there was no clear regularity in the color planning, it must have been laid out according to Taut's sense of design.

By making the architectural model, it became clear that his color planning seems to have changed in the short period of time between section one, constructed between 1925 and 1926 in the northern area of the site, and section two, constructed between 1926 and 1927 in the southern area (Fig. 1). For example, the townhouses along Lining street in the northeastern area show a unique coloration that is different from other streets, i.e., the whole building is colored blue (Fig. 5). On other streets, blue residences are placed only at the ends of townhouses (Fig. 6); therefore, it can be speculated that Taut's usage of blue changed after the construction of Lining Street. There are also buildings on this street on which two colors alternate between every house, like stripes (Figs. 4, 5), a coloration which is not found elsewhere. Moreover, on many townhouses in section one, the colors of the garden-side wall are different from those of the street-side wall, while most of the townhouses in section two have the same colors on both sides.

We can say that the coloration of section two is more systematic than that of section one. For example, in section two, the buildings on Jochen-Nussler Street in the southeastern area are of great interest as they show a gradual transition from white to yellow to red in a zigzag pattern (Fig. 7). This allows us to potentially see an aspect of Taut's stance on systematic color planning.

5. Conclusion

This paper discusses Bruno Taut's Britz housing estate as an example of color planning in modern architecture. Taut's color planning became more systematic after designing the Britz housing estate. Through analyzing an architectural model, the author observed that it changed between the creation of sections one and two of this project.

During the Weimar Republic, many modern architects, not only Taut, dealt with color. By considering the other architects' works, the progression of color planning in modern architecture may be traced more explicitly.

Acknowledgment

The author would like to thank Mr. Kentaro Tsutsumi for constructing the architectural model. I also thank Mr. W. Brenne and Mr. Jens Rieser for their advice and provision of materials.

Notes

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2. B.Taut, "Farbe", *Gehag-Nachrichten,* I 6, 1930

3. *Gross-Siedlung Britz: Dokumentation und Rekonstruktion des Originalzustandes* (Band 2A, 2B, 3A, 3C), Berlin, 1984-91

4. M.Ebisawa, "On the planning of residential buildings and their colors in the Hufeisensiedlung Britz by Bruno Taut", *Summaries of technical papers of annual meeting of AIJ*, 2019 (in Japanese)

Fig. 2 The Horseshoe-shaped building

Fig. 3 The Red Front

Fig. 4 Townhouses, Lining Street

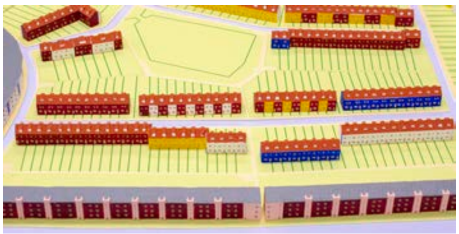

Fig. 5 Model of townhouses, Lining Street

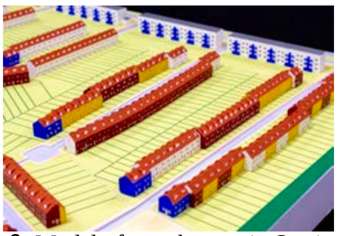

Fig.6 Model of townhouses in Section 2

Fig.7 Model of townhouses, Jochen-Nussler Street

A Critical Assessment of German Classic and Modernist Ideas of Colors

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ABSTRACT

This paper contributes to reevaluation of German classic ideas of colors, especially of Goethe. First, the outline and feature of Goethe's theory of color is described. Next academic relation between Goethe and Hegel on color is considered from the development of Hegel's philosophic logic. Then we compare some modernist remarks on German classic thoughts of color from contemporary Aspect.

1. INTRODUCTION

Goethe (1749-1832), well known as the writer of the play "Faust", devoted his energies not only to literature work, but has occupied himself also a good deal with study of the natural sciences. The science of colors is for him beyond a principle subject matter. It is rather his life work. Today, his attacks on Newton's theory of colors turned out to be fundamentally flawed, whereas his master work "Zur Farbenlehre"(1810) privides even now various inspirations for scholars and artists. This paper reappraises German classic and modernist ideas of colors from the contemporary philosophical point of view.

2. GOETHE ON COLOR

2.1 Origin

Goethe's gigantic work "Zur Farbenlehre" is nominated for the most important contribution to the science of colors. A distinguishing feature is his systematic understanding of color phenomenon, which is represented especially by his "Farbenkreis" (color circle) with the notion of polarity.

Goethe's inquiry into colors had many years duration, before the publication in a form of the book in 3 volumes 1810. His academic activity on colors began from a small discovery in January 1790. He did an experiment with prism, in order to test out Newton's doctrine of colors. The observation and judgement then played a crucial role in the formation of Goethe's ideas of colors. His investigation was motivated by a conviction that colors originate from lively interaction of light and darkness, white and black. [1]

The idea of dualistic constitution of chromatic system can be traced back to Aristotle. Aristotle, who analyses colors and human senses in "Περὶ Ψυχῆς" (On the Soul), defines in "Περὶ αἰσθήσεως καὶ αἰσθητῶν" (On Sense and the Sensible) color (χρόα) ; "the limit of the translucent in determinately bounded body" (439a). He explains the genesis of various colors with respect for the oppositional relationship of light and darkness(439a). Goethe's Theory is rooted deeply on the Aristotelian tradition of philosophy.

2.2 Polarity of colors

Goethe formulated "Farbenkreis", based on the idea of dualistic opposition of colors, not later than July 1793. He explained it in §50 of "Didaktischer Teil" 1808 as it follows: "Considered in general point of view, color is determined towards one of two sides. It thus presents a contrast which we call a polarity and which we may fitly designate by the expressions plus and minus."[2] Later he wrote on the chromatic opposition in a notebook of natural scientific study(1817-22), and characterizes the colors in opposition as "colors which demands each other", and calls them "complementary" [3]. Goethe is counted as the earliest proponents of the notion "complementary colors".

3. GOETHE AND HEGEL

3.1 Hegel as an apologist for Goethe

Goethe's "Zur Farbenlehre" could not have a good reputation just after its publication. It was refused by not a few scientists except for a tiny minority of exceptions. In such a difficult circumstance little number of scholars took side of Goethe. But one of them is Hegel (1770-1831).

In the part of philosophy of nature in "Encyclopedia of philosophical sciences" (1830) he expresses his approval of Goethe's criticism of Newton's Theory [4]. He acknowledges himself to be an apologist for Goethe saying that "it is to Goethe we owe the theory of color adequate to the notion. He was early drawn to study of color and light, especially in connection with painting; and his pure, simple feeling for nature, the first requirement for a poet, forced him to oppose barbarisms of reflection such as we find in Newton." [5] Hegel also understands color, basically following the doctrine of Goethe, with regard to the dualistic relation of light and darkness.

3.2 Hegel's approaching to Goethe's theory

Hegel's during his life time unpublished manuscripts of lectures on philosophy of nature(1803/04) indicates that already in 1803 Goethe's theory of color was mentioned in lectures [6]. Indeed, It is a noteworthy evidence, because Hegel referred to it before its publishing to the general public. But a simple question arises at the same time: how and when he got aware of it. There is a speculation, which is given by the editorial note of Hegels Gesammelte Werke Band V, that he was already in his early days informed of it by a philosopher Schelling (1775-1854), who agreed with

Goethe on his criticism against Newton [7]. Hegel's acknowledgement of Goethe's theory is dated possibly earlier than 1803.

3.3 Hegel's philosophy of arts

Hegel mentions Goethe's theory in his lectures on philosophy of Arts too. He says as following: "Now the beauty of their [=direct opposites, like yellow and blue] harmony consists in avoiding their sharp difference and opposition which as such is to be obliterated, so that in their differences their unison is manifested. For they belong together, since color is not one-sided, but an essential totality. The demand of such a totality can go so far, as Goethe says, that even if the eye has before it only one color as its object, it nevertheless subjectively sees the others equally." [8] The idea of "essential totality" of color plays a principal role in the formation of his theory of Aesthetics, also in the development of the dialectical logical thought of philosophy.

4. SOME MODERNISTS' REMARKS

4.1 Influences

German classic ideas of colors, esp. by Goethe, are even today giving rise to many debates on the essence of color. For example, the theory of dualistic opposition of colors, which is shared between Goethe and Hegel, leads to Evald Hering's "Gegenfarbentheorie" (theory of color opponency) in 1878

Besides, the color education in the BAUAUS school in Weimar and Kassel succeeded to the classic idea of color.

4.2 Weizsäcker

In 20th century, a german physicist Carl Friedrich von Weizsäcker (1912-2007) admits Goethe's failure in his polemic against Newton, whereas Weizsäcker stresses that the concept of totality in Goethe's theory doesn't lose its meanings. [9]

4.3 Wittgenstein

Another remarkable example is Wittgenstein (1889-1951) and his philosophical investigations on colors. The philosopher studied very late in his life Goethe's "Zur Farbenlehre". He was then a critically ill patient, but he had started on a philosophical book on color; "Remarks on Color". He mentions everywhere in the book Goethe's theory of color. For instance, "Goethe's theory of the origin of the spectrum isn't a theory of its origin that has proved unsatisfactory."(3rd Part §125) "We do not want to establish a theory of color, but rather than the logic of color concepts."(1st Part §22) [10] In these sentences, Wittgenstein expresses in his own style his approval towards Goethe's theory of color.

5. CONCLUSION

Goethe's approaches to color, which we might call subjective and aesthetic one, have been recently reevaluated by some scholars. D. L. Sepper reassessed Goethe's polemics regarding new scientific researches of color. [11] It just turned out in this research project that the German classic ideas of colors, in particular Goethe's theory of colors, contain various remarkable points from contemporary viewpoint.

5. REFERENCES

[1] "Wie sich die einzelne Farbe auf Licht und Finsternis als ihre erzeugenden Ursache beziehen: so bezieht sich ihr körperliches, ihr Medium, die Trübe, auf das Durchsichtige." (J.W.v.Goethe, Die Schriften zur Naturwissenschaft [Leopoldina], Verlag Hermann Boehlaus Nachfolger Weimar, Abt.1, Bd.8, S.226-7)

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[3] J.W.v.Goethe, Die Schriften zur Naturwissenschaft [Leopoldina], Abt.1, Bd.8, S.190

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[11] Dennis L. Sepper "Goethe contra Newton" Cambridge Uni. Press 1988

Preparation of Color Samples of Graphite Intercalation Compounds: Analysis and Use of Colors

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ABSTRACT

Graphite intercalation compounds (GICs) exhibit various colors depending on the materials used for intercalation and their concentrations. The color of a GIC, which suggests its electrical properties, is the most important characteristic of a GIC. In this study, we synthesized graphite compounds with many different types of intercalated materials, such as alkali metals, metal chlorides, acids, and amalgams to obtain GICs that display a range of striking colors. Here we present a summary of the color images of the GICs together with their synthetic procedures, structures, and selected physical properties.

1. INTRODUCTION

Graphite has a layered structure, with each layer consisting of a sheet of hexagons, each of which contains six carbon atoms. These layers form a stack of horizontal sheets that are held together by weak bonds. This structure therefore enables other chemical species to enter the space between consecutive graphite interlayers to form graphite intercalation compounds (GICs), as shown in Fig.1. The intercalation process is accompanied by charge transfer between the graphite layers and the intercalated species and the number of electronic carriers, i.e., electrons or holes, increases to 10^2-10^3 times. As a result, the GICs have higher electrical conductivities than the graphite host. Certain GICs have been reported to have electrical conductivities higher than those of metallic copper. Therefore, GICs are classified as synthetic metals.

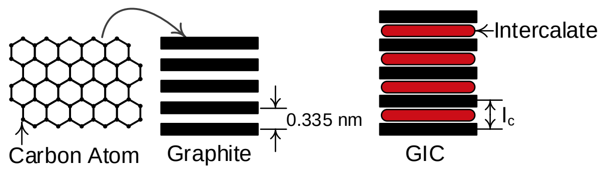

Fig.1 Graphite and GIC.

Another striking characteristic of a GIC is its color. The appearance of graphite is black or dark gray with luster. On the other hand, the color of a GIC depends on the intercalated species and its concentration. The color change is also derived from charge transfer. Even though the color of a GIC is one of its most important characteristics, investigations of the color, especially color images, have rarely been published. We believe these data and results to be necessary to advance the development of GICs.

In this study, we prepared color samples of a few types of GICs and here we summarize their color images together with their synthetic procedures, structures, and physical properties. In this presentation, we mainly introduce the photographic images and Raman spectra we recorded of the GIC samples.

2. EXPERIMENTAL

2.1 Samples

The graphite host we used mainly comprised PGS graphite sheets (Fig.2), which are flexible and highly oriented thin graphite sheets (Panasonic, 0.1 mm depth). In addition, other types of graphite such as natural graphite powder were also used. The GIC samples were synthesized by a vapor phase method under vacuum. Specifically, the graphite and reagents were sealed in a glass tube under vacuum and heated. Table 1 is the list of prepared GIC samples with their reaction conditions.

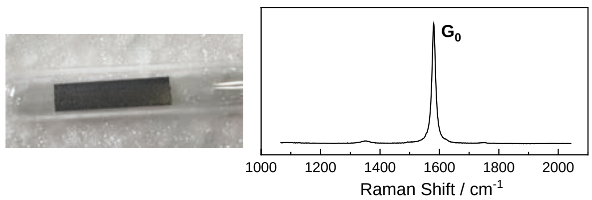

Fig.2 Image and Raman spectrum of PGS.

Table 1 GIC samples and their reaction conditions.

Type	Reagents	Heating
K-GIC	K	200 ^oC, 24-72h
Rb-GIC	Rb	200 ^oC, 24-72h
K-Hg-GIC	K, Hg	210 ^oC, 7d
$FeCl_3$-GIC	$FeCl_3$	300 ^oC, 15-72h
$MoCl_5$-GIC	$MoCl_5$, MoO_3	300 ^oC, 24-72h
$CuCl_2$-GIC	$CuCl_2$, $AlCl_3$	500 ^oC, 15h
$AlCl_3$-GIC	$AlCl_3$, $C_4H_4ClNO_2$	115 ^oC, 24h
H_2SO_4-GIC*	H_2SO_4, HNO_3	r.t., >3d

* Prepared by liquid method.

2.2 Photographic images

As GICs are unstable in air, the GIC samples were kept encapsulated in the glass tube under vacuum. The images of the GIC samples were captured through the glass by using the camera of an i-Phone 7 mobile device.

2.3 Measurements

Raman spectra of the GIC samples sealed in glass cells under vacuum were recorded to determine their stage structure by using an NRS-5500 instrument (Jasco, 532 nm laser line). After each sample was exposed to air, its

X-ray diffraction patterns were recorded to detect the period (I_c) in which the GIC could be identified. In addition, electrical properties such as the electrical conductivity were also measured.

3. RESULTS AND DISCUSSIONS

3.1 Alkali-metal GICs

Alkali-metal GICs are the most popular GICs with Li, K, Rb, and Cs easily being intercalated into the interlayers of the graphite structure. Figure 3 shows samples of the stage 1 and 2 structures of K-GIC prepared from PGS. Alkali-metal GICs have a golden color in stage 1 (the composition is KC_8) and appear blue in stage 2 (KC_{24}). The higher stage structures appear more dark blue to black.

Figure 4 shows the Raman spectra of stage 1 and 2 for Rb-GIC. The G_0 band at 1580 cm^{-1} of the graphite structure shifts as a result of intercalation, and the G_1 and G_2 bands appear at 1600 cm^{-1} and 1620 cm^{-1}, respectively. However, stage 1 alkali-metal GICs are known to exhibit quite different Raman shifts, caused by an in-plane structure that differs from those of the higher stages [1].


Stage 1 Stage 2

Fig.3 Photographic images of stage 1 and 2 K-GICs.

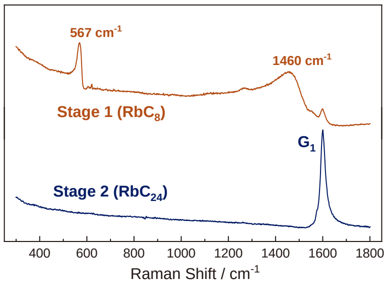

Fig.4 Raman spectra of stage 1 and 2 Rb-GICs.

3.2 Metal Chloride GICs

Many kinds of metal chlorides can be intercalated to form GICs. We selected $FeCl_3$, $CuCl_2$, $MoCl_5$, and $AlCl_3$ GICs for our work, because these are easily synthesized and form the stage 1 structure. Images of these GiCs are shown in Fig.5. The colors of metal chloride GICs, which are darker compared with those of alkali-metal GICs, are mostly blueish green with a slight metallic luster, while $AlCl_3$-GIC is dark blue. The surface morphology is uneven because of bubbles of chlorine gas generated during the reaction. The three GICs, $FeCl_3$-, $MoCl_5$-, and $AlCl_3$-GICs, almost have the same I_c values and electrical conductivity.

Figure 6 shows the Raman spectra of the stage 1 and 2 $MoCl_5$-GIC. Stage 1 exhibits only the G_2 band, whereas stage 2 mainly exhibits the G_1 band. The stage 2 $MoCl_5$ -GIC is gray in color.

Fig.5 Images of stage 1 $FeCl_3$-, $MoCl_5$-, and $AlCl_3$-GICs.

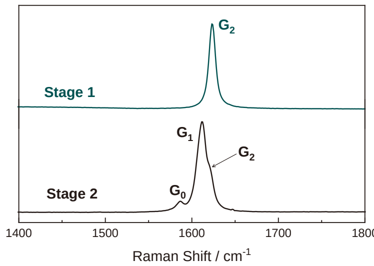

Fig.6 Raman spectra of stage 1 and 2 $MoCl_5$-GICs.

3.3 Other GICs

The molecules of certain acids can intercalate with graphite. Here, we prepared H_2SO_4-GIC. The GIC structure containing H_2SO_4 was obtained by simply submerging a piece of graphite into a liquid mixture of H_2SO_4 and HNO_3 in ambient atmosphere. The resulting GIC was blue-green in color with a slight metallic luster as shown in Fig.7 and the structure was stage 1.

Amalgams with alkali metals are also well-known intercalates of GICs, with K amalgams reported to be pink in color. In this work, we attempted to prepare the K-Hg GIC with the composition $KHgC_4$ and succeeded in confirming the bronze-pink color, as shown in Fig.7.


H_2SO_4-GIC K-Hg-GIC

Fig.7 Images of H_2SO_4- and K-Hg-GIC.

4. SUMMARY

GICs with alkali metals, metal chlorides, acids, and amalgams were synthesized by using PGS graphite sheets and color photographic images of these GICs were taken. In addition, their structures and properties were investigated. The study is presently continuing and we aim to conduct various measurements in future. We plan to prepare additional beautiful GIC samples with HOPG (highly oriented pyrolytic graphite) and to capture images and carry out color measurements. We also aim to estimate the magnitude of electron transfer by measuring the magnetoelectric properties to briefly assess the relationship between the color and these properties.

ACKNOWLEDGEMENTS

The authors thank Dr. N. Akuzawa for his support in synthesizing of K-Hg-GIC samples.

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Development of multicolor-holographic flip-books systems using lithium-niobate crystals

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ABSTRACT

A multicolor holographic flip-books system is presented, in which angle-multiplexed image plane holograms are recorded using an Fe-doped $LiNbO_3$ (LN) crystal as recording media with a 532-nm green laser. A 633-nm red He-Ne laser, the 532-nm green laser, and a 432-nm blue diode laser were used to illuminate the recorded holograms. Multicolor flip-books are obtained when the LN crystal was slowly rotated. Bragg mismatching from the use of three wavelengths is compensated by changing the reconstructing angles.

1. INTRODUCTION

We describe a multicolor-holographic flip-books system using Fe-doped $LiNbO_3$ (LN) crystals. By using the system, color animation can be observed by rotating the crystal about the half angle of the recording beam.

Being different from the conventional hologram recorded on a thin recording material, volume hologram using a thick material allows the angle-multiplexed hologram recording [1]. Thus, volume hologram has proved to be very useful for optical memory due to the large storage capacity and fast transfer rate. Moreover, photorefractive materials like LN crystal can be used as a rewritable recording media, the images can be erased and rewritten again. Thanks to the angle-multiplexing property, it's interesting to use the LN crystal as a holographic recording material for recording multicolor flip-books.

Fourier-transform scheme has been used to record the hologram in LN crystals. However, Bragg-mismatch occurs when we use a light source with a different wavelength for hologram reconstruction. We will be able to get only a part of image rather than a whole original image since volume hologram acts as a band pass filter getting through the bandlimited spatial frequencies of an input image. Several techniques have been proposed to relieve that problems: using a spherical [2] or polychromatic [3] reconstructing wave to match the Bragg condition. On the other hand, an image hologram [3] can produces a whole image. We demonstrate the whole-image reconstructions from an image-plane volume hologram with a Fe-doped LN crystal. A LN volume hologram can record a number of multiplexed images with the rotation of a crystal [4].

2. CONCEPT

The concept of the proposed multicolor-holographic flip-books system [5,6] is schematically shown in Fig.1. The images forming the flip-books are multiply recorded on an LN crystal as holograms while the LN crystal is rotated by an angle of 0.2°. After that, we can observe a color animation by rotating the LN crystal with respect to a laser beam, otherwise by using a LED broad-spectral source [7].

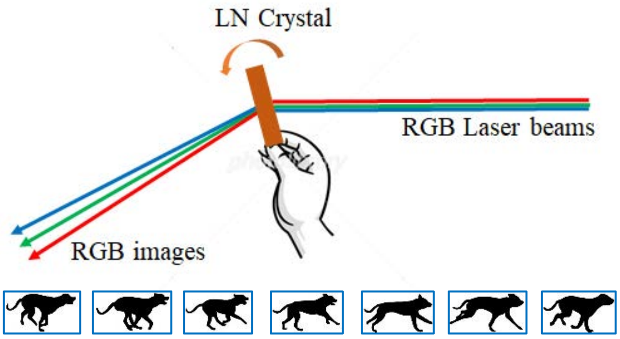

Fig. 1 Concept of the flip-books

3. THEORY AND OPTICAL SYSTEM

Fig. 2 shows a schematic configuration of the optical system used for recording and reconstructing the flip-books system.

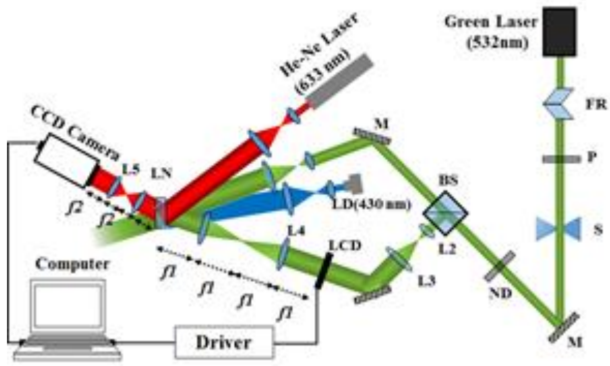

Fig. 2 Optical setup

A diode-pumped solid-state (DPSS) laser (Coherent Compass 315M-100SL, 532nm, 100mW) is used for recording the holograms. The light beam from the DPSS laser is split using a Beam-split into two beams. One is used to illuminate a liquid-crystal device (LCD) on which the input images were displayed, and the light wave passing through the LCD was imaged with a *4-f* optical system onto the LN crystal as the object wave. The other beam is expanded and then used as a reference wave. The object and reference waves with a cross angle of 30° overlapped on the LN crystal and form an interference fringe patterns. In the bright region of the fringe patterns, the electrons of Fe level were excited, moved to dark region and finally formed a space-charge field that produces a space refractive index distribution via Pockels effect. In this way the input image was recorded on the LN crystal as a transparent image hologram. Because of the sharp Bragg condition, the next image can be recorded by slightly rotating the crystal.

In multi-color observation of the flip-books, a He-Ne laser (632.8nm, 10mW), a DPSS laser described above, and a diode-laser (432nm, 8mW) were used as light sources. The incident angle θ_R for a red laser beam and θ_B for a blue laser beam are set as $\theta_R = \sin^{-1}\left(\lambda_R / \lambda_G \cdot \sin\theta_G\right)$ and $\theta_B = \sin^{-1}\left(\lambda_B / \lambda_G \cdot \sin\theta_G\right)$ to match the Bragg condition due to the wavelength difference between the recording and readout lasers.

4. EXPERIMENTAL RESULTS

4.1 Exposure time reduction

In our experiments, a Fe-doped LN crystal of 10-mm square and 4-mm thickness was used. Usually, a relatively long time up to several minutes was required to record the hologram into LN crystal. We developed the recording efficiency for different polarization condition for the first time. The p-polarization is quite better than s-polarization usually used. The intensity dependence on the exposure time is shown in Fig. 3. The exposure time can be reduced from hundreds to seconds.

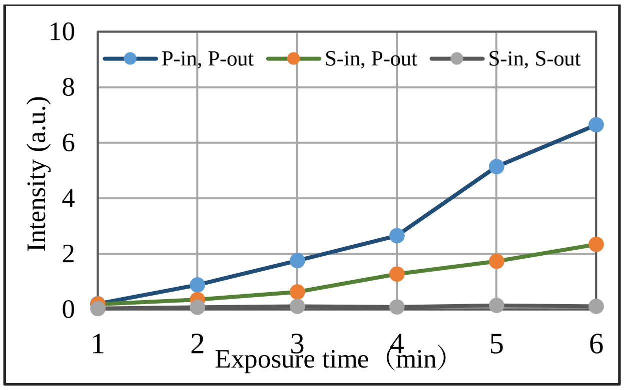

Fig. 3 Reconstruction image intensity at different polarization condition

4.2 Angle separation

Another important issue in forming flip-books is angle separation. We found there is no cross talk with a minimum angle separation of 0.2°as shown in Fig. 4.

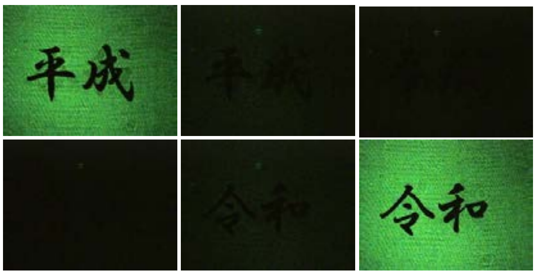

Fig. 4 Reconstructed images with an angle-separation of 0.2°

4.3 Demonstration of color flip-books

As a demonstration, multi-color flip-books was made. During the experiments, the original images was send to LCD one by one, and recorded with the reference beam, while the LN crystal was rotated by 0.2 degree between two adjacent images.

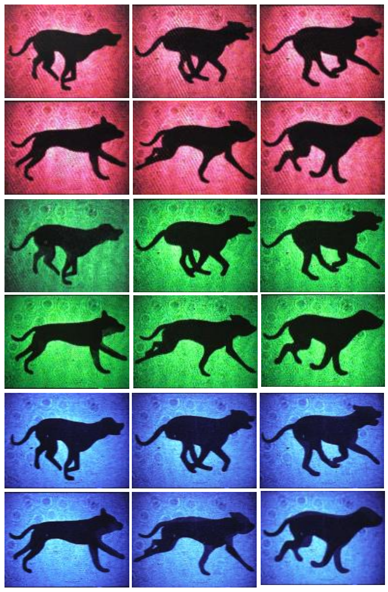

Fig. 5 Demonstration of a RGB color flip-books

5. CONCLUSION

A multicolor holographic flip-boos system is presented. The original images were recorded on a rewritable photorefractive media, Fe-doped LN crystal, we can observe a color animation by slowly rotating the crystal with RGB illumination laser lights. By optimize the incident light polarization condition, the exposure-time reduction from hundreds to seconds enabled us to easily record a large amount of images into the crystal.

6. Acknowledgment

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The Art of Color Science: Individual Differences

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ABSTRACT

The fundamental data of color science are color matching functions, which represent the spectral absorption properties of cone photoreceptors. All colorimetry follows from these functions, which, in standard form, are intended to represent the average sensitivities of the population of human observers with normal color vision. Individuals are, however, individual and have their own color matching functions and other visual responses that naturally vary from the mean. This paper provides a review of the nature and magnitude of individual differences in color matching functions and other mechanisms of color perception along with suggestions for practical systems to account for individual differences in colorimetric practice.

1. The Big Questions

The two big questions discussed in this paper are (1) What do you see? And (2) Do you see what I see? Such questions often cross into the domain of the psychology and philosophy of perception [1] or into the insoluble questions of qualia [2] (*e.g.*, is what you perceive when seeing a stimulus described as red the same is what I perceive when seeing a stimulus described as red).

However, these questions can be addressed to a degree from a more fundamental level. This is accomplished by examining individual differences in the absorption of light by the three cone classes in various observers (individual differences in color matching functions) and the anatomy and physiology underlying them. The phenomena of individual differences in color matching functions is often described under the rubric of observer metamerism (two stimuli that match in color to one observer might mismatch to another). In addition, this paper examines individual differences in the higher-order mechanisms of chromatic adaptation.

2. Color Matching Functions

The CIE standard colorimetric observer was first defined in 1931 (with a second version established in 1964 for larger fields of view) as well understood and utilized in practical colorimetry.[3] These functions were intended to represent the color sensitivities of a mean, or average, observer and they have performed admirably in that role for nearly a century. It has also long been known that individual observers exhibit significant variation about those means in their color matching function data.[4] However, until recently, there were neither resources for, nor interest in, carefully defining individual color matching functions and the variance of the population.

One approach to efficiently defining individual color matching functions has been *Monte Carlo* simulation of the various physiological parameters that make up color matching functions (lens, macula, pigments) in order to synthesize individual functions.[5] Such techniques have proven quite accurate and effective. In addition, the CIE, in 2006, defined more accurate mean functions for variable age and field size [6] and Asano *et al.* refined the *Monte Carlo* techniques to the point that individual observers could be accurately modeled and characterized.[7]

Ultimately, these advances have allowed systems of individual colorimetry to be practically implemented and the first practical system to predict both mean color matches and confidence volumes about such matches representing the spread of the observer population as first suggested by Nimeroff *et al.* in 1961[8] and as pursued by the author for approximately three decades.

3. Chromatic Adaptation

Once cone signals are established through absorption of light according to the cone responsivities (*i.e.* color matching functions), they are subject to the mechanisms of chromatic adaptation to produce signals that ultimately correlate with color appearance. While it is well established that there are individual differences in color matching functions, the question of whether there are additional individual differences in chromatic adaptation mechanisms (not due to the CMFs themselves) remains open. One reason this has not been previously explored in the context of color appearance is that corresponding colors data, required to quantify chromatic adaptation mechanisms, are often very imprecise and any potential individual differences are masked by uncertainty in the results. Once averaged across observers, corresponding colors data are well described using the von Kries hypothesis, and modern implementations of what is now called the von Kries model, that dates back more than a century.[9]

More recently, research has been completed to obtain significantly more precise corresponding colors data.[10] These results indicate that there are very significant individual differences in chromatic adaptation and that it might be necessary to have individual models of chromatic adaptation, in addition to individual CMFs, in order to properly predict appearance.

Additionally, the results indicated that it might be possible that chromatic adaptation is not reversible.[11] In other words, when given a reference color under light source A and asked to select a corresponding color under light source B, the answer might differ from the reverse task when the reference is under source B and the match is selected under source A. Chromatic adaptation might not follow a transitive property across changes in illumination. This result is surprising and requires additional data to be confirmed. Such research is now underway.

Putting this all together allows improvements in a variety of applications such as the potential for individualized color reproduction for high-quality applications and quantifying the individual variability in assessment and specification of the color rendering properties of illumination.[13]

4. A Note On Tetrachromacy

One topic of individual differences that has recently sparked more interest than warranted is the potential for tetrachromacy in female carriers of anomalous trichromacy. The potential for female trichromacy was discussed as early as 1948[14] and speculated upon decades earlier.[15] Because these females, especially if they have one son with normal color vision and another with anomalous trichromacy, have the genetic coding for four distinct classes of cones, it is likely that they have four classes of cones in their retina. However, what seems likely, and perhaps ubiquitous, is that these women still have trichromatic color appearance such that the four cone classes are fed into three color responses at some point in the visual system. No female observer has yet been identified with strong tetrachromacy (a four-dimensional color space) although Jordan *et al.*[16] did manage to find one female carrier out of 24 evaluated that showed some signs of additional discrimination ability. However, the extra dimension was not fully established in that work and there are no indications of observers who cannot function with trichromatic color reproduction (*i.e.* would require a fourth primary in imaging systems) so it is possible there are not functional, or strong, tetrachromats despite the potential being there.

6. Conclusions

Colorimetry has been successful for nearly a decade based on the psychophysical measurement and modeling of average, or mean, observers in terms of color matching functions and chromatic adaptation models. More recent data suggest that individual differences in both can have significant impact on the correlation between predicted matches and appearance and individual visual assessments. Fortunately advances are underway to allow colorimetry to be personalized for individual differences in both aspects of color perception and the promise for an improved future system of colorimetry is strong.

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Powder electroluminescent device based on paper substrate for designing multi-functional digital signage

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ABSTRACT

We demonstrated the emissions of multi-colored light from a powder electroluminescent device using a thermochromic material through a temperature control. At room temperature, the emission of a sapphire blue light from the device was observed under the application of an alternative current voltage. With an increase in the temperature, the color of the thermochromic materials changed from orange to white, leading to sky blue emissions from the device owing to the decrease in energy transfer from the excited state of the phosphor to the thermochromic material.

1. INTRODUCTION

To realize a Super Smart Society, namely, Society 5.0, many different types of electronic devices must be connected to the global network at any time and in any location. In such a society, the devices must not only achieve flexibility with the ability to easily attach to the surface of a curved object such as paper, they must also have a workability allowing them to be cut into an arbitrarily shape. Display devices with a human machine interface also require such functionalities. However, a conventional liquid crystal display device uses a hard glass substrate and a light-emitting diode backlight. In addition, an organic electroluminescent (EL) display device must block the oxygen and water to prevent an unfavorable reaction. Thus, such displays cannot achieve the above requirements.

To overcome this, we focused on a powder EL device that achieves numerous advantages, including a high throughput, workability, weatherability, and stable bendability. With regard to the bending durability, we demonstrated powder EL devices on an Ag grid laminated with Poly(3,4-ethylenedioxythiophene)-poly (styrenesulfonate) (PEDOT:PSS) that achieves a successfully demented bending durability of 20,000 cycles [1, 2]. Despite such advantages, the commercial applications of this device remain a niche market in its present state. To realize new applications, a powder EL device with a multiple functionalities should be achieved. For this reason, we introduced a thermochromic (TC) material that can enable a reversible color change in a powder EL device through an external heat stimulus, thereby achieving a novel powder EL device that exhibits multi-color light emissions from a change in temperature. In this study, we introduced a TC layer that enables a color change in a device from orange to white at 40 °C, and evaluate the electrical and optical behaviors.

2. EXPERIMENTAL

2.1 Materials

Tracing paper applied as a substrate was purchased from Sakae Technical Paper Co., Ltd. Zinc sulfide (ZnS)-type particles (GG65) used as a phosphor layer were purchased from Osram Sylvania. Barium titanium oxide ($BaTiO_3$) utilized as a dielectric layer was purchased from Kishida Chemical Co., Ltd. Cyanoresin (CR-V) applied as a high dielectric polymer was purchased from Shinetsu Chemical Co., Ltd. Cyclohexanone used as a solvent was purchased from Fujifilm Wako Pure Chemical Co. PEDOT:PSS applied as a transparent electrode was purchased from Sigma-Aldrich Co., LLC. The encapsulated TC materials utilized as a TC layer were purchased in a slurry form from Kirokusozai Co., Ltd. Finally, Ag-paste for application as a back electrode was purchased from Mino Group Co., Ltd.

2.2 Preparation of the EL devices

The high-dielectric polymer paste was prepared by mixing cyanoresin and cyclohexanone at a weight ratio of 3:7. The phosphor particles and $BaTiO_3$ were dispersed in a high-dielectric polymer paste at a weight ratio of 4:6. These functional materials were laminated using an automatic screen printing machine (TU2020-C, Seritech Co., Ltd.) (Fig. 1). Each material was sintered in a constant-temperature oven (FS-405, Yamato Scientific Co., Ltd.) at 150 °C for 6 min. The transparent electrode was sintered for 40 min.

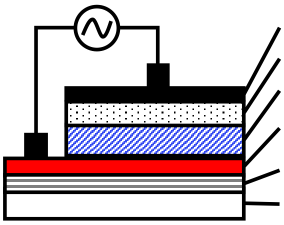

Fig. 1 Structure of powder EL devices

2.3 Photophysical and EL measurements

Ultraviolet-visible (UV-vis) absorption spectra of the films were measured using a spectrophotometer (OP-TR/RF-GONIO-MN, Ocean Photonics). Photoluminescence spectra were obtained using a spectrofluorometer (FluoroMax-3, Horiba). The excitation wavelength of the films was 350 nm. The voltage dependences of the current and the luminance of the prepared devices were measured using an EL measurement system (SX-1152, Iwatsu Electric CO., Ltd.).

3. RESULTS AND DISCUSSION

Fig. 2 shows the normalized photoluminescence (PL) spectrum of the phosphor layer and the absorbance spectra of the TC layer in the initial and heated states. The PL spectrum of the phosphor showed a peak at 450 nm. By heating the TC layer to 40 °C, the absorbance within the visible light region was decreased. This change in the absorbance band in the TC layer and the PL spectrum of the phosphor overlap well. Such an overlap with the absorption and emission bands facilitates an energy transfers between the phosphor and TC layers.

Fig. 3 shows the current and luminescence dependence of the voltage in powder EL devices with/without a TC layer at room temperature. With the introduction of the TC layer, the current of the powder EL device decreased to 0.36 mA, which is 0.45-times lower than that of the powder EL device without a TC layer (0.80 mA). Corresponding to this result, the luminance is also lower. It is thought that the electrode distance increases by the introduction of the TC layer.

To demonstrate the multi-color EL by utilizing a change in the external temperature, we measured the EL spectra of the device in the initial and heated states under the application of an AC voltage of ±170 V at 1.2 kHz (Fig. 4). In the initial state, a sapphire blue EL band with three emission peaks at 450, 490, and 550 nm was observed because the device was in a colored state. By contrast, in a heated state, the color of the device changed from orange to white, and the sky blue EL band with an emission peak 450 nm is almost identical to that of the PL spectrum (Fig. 2). The intensity at 450 nm of the device in a heated state was 2.5-times higher than that in the initial state. These results indicate that the EL color of the EL device can be controlled through the energy transfer between these materials.

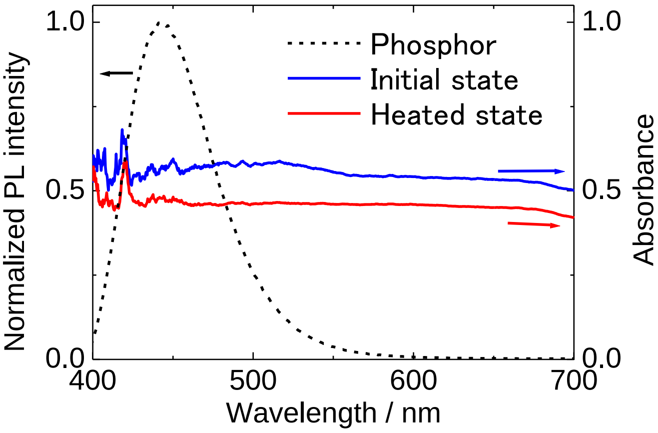

Fig. 2 PL spectrum of the phosphor layer and absorbance spectra of the TC layer in the initial/heated states

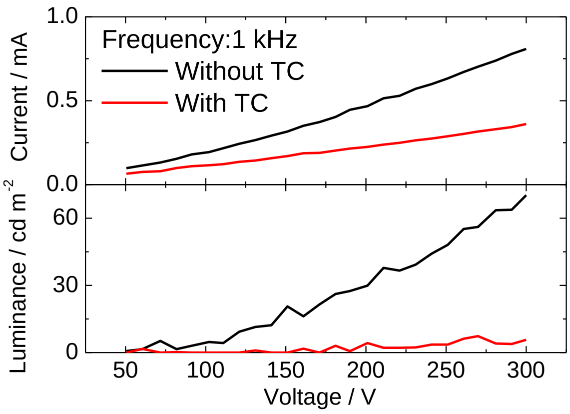

Fig. 3 Current (top) and luminescence (bottom) dependence of the voltage in powder EL devices with/without TC layer

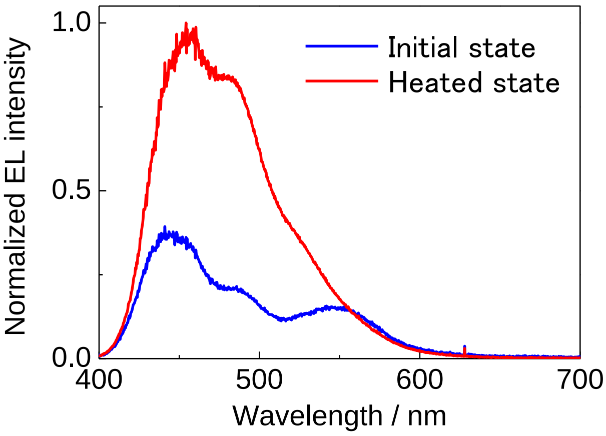

Fig. 4 Normalized EL spectra of the device in the initial/heated states under the application of ±170 V at AC voltage of 1.2 kHz

5. ACKNOWLEDGMENTS

This work was supported by “FY2016 MEXT Private University Research Branding Project” and the Ebara Hatakeyama Memorial Foundation.

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Durability Improvement of Electrochromic Display with Nano-Structured Electrode

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ABSTRACT

Au nano-islands were immobilized on ITO electrodes by pulse electrolysis. Poly(pyrrole) [PPy] was electrochemically polymerized using the nano-structured electrode (Au-ITO). The electrochromic changes of PPy on the Au-ITO could be more stable than one on an untreated ITO electrode.

1. INTRODUCTION

Recently, we reported that the electrochromic (EC) response of conductive polymers could be improved by using Au nano-particles with island structure immobilized on transparent electrode. These nano-structures were easily obtained by sputtering or electrochemical deposition. In order to improve the EC response, the enhancement of coloring by plasmonic electric fields of Au nano-particles (with a particle size of several tens of nanometers) contributes to the thinning of EC material films. [1,2] The dielectric-metal-dielectric (DMD) structure formed between these particles probably improve the electrical conductivity of the EC material.

The stability of EC changes was focused on this study as the effect on the EC characteristics by using the nano-structured electrode. It is well known that the redox reaction of conductive polymer is accompanied by a large and powerful volume changes. We believe that the polymer film detachment from the electrode due to volume changes play the great role to the deactivation of the EC changes.

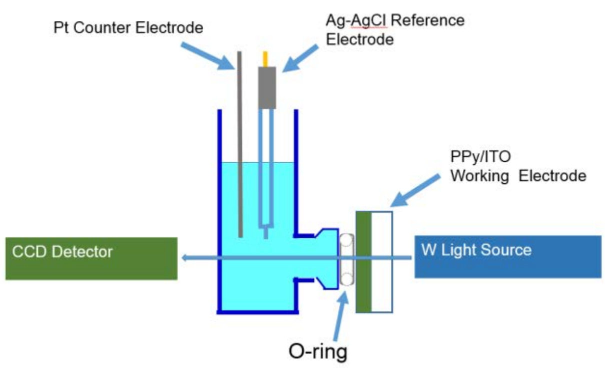

Fig. 1 Schematic diagram of the transparent glass cell.

2. Experimantals

2.1 Preparation of ITO Electrode Modified with Au Nano-island (Au-ITO)

Au nano-island was immobilized on ITO electrode by electrochemical deposition with pulse voltage (11 V) and constant voltage (1.0 V). This reaction was carried out using an aqueous solution of Au (I) trisodium disulphite and potassium sulfite at room temperature.

2.2 Preparation of Poly(pyrrole) Film

The PPy films were prepared on the electrode by an electropolymerization with a cyclic potential application between -500 mV and +800 mV (vs. Ag-AgCl, scan rate: 50 mV/s). The polymerization solution was 10 mM pyrrole and 0.1 M lithium perchlorate ($LiClO_4$) dissolved in water.

2.3 Transmittannce measurement

The EC characteristics of the PPy on the electrode were evaluated by the transmittance measurement in the transparent glass cell. Fig. 1 shows the schematic diagram of the transparent glass cell.

3. RESULTS AND DISCISSION

3.1 Polymerzation

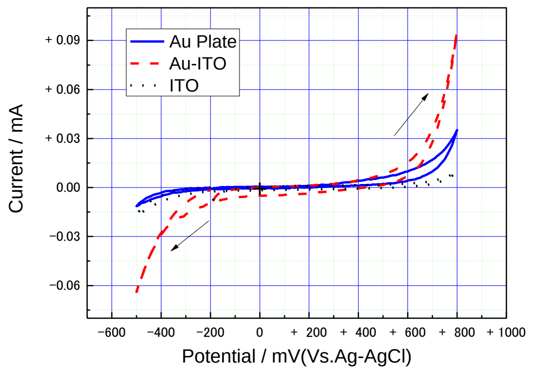

Fig. 2 Cyclic voltammograms (scan rate : 50 mV/s) of the pyrrole polymerization on ITO, Au-ITO and Au plate electrodes at the first potential scanning.

Fig. 2 shows cyclic voltammograms at the time of the first scan during polymerization using the ITO electrode and the Au-ITO electrode. Comparing the monomer oxidation currents at +800 mV, the Au-ITO shows about 10 times larger current value than the ITO electrode. Generally, this current is considered to be a mixture of a current for monomer oxidation and a current for oxidation of a polymer adsorbed (or deposited) on an electrode. On the cyclic voltammogram, oxidative currents for potential scan in negative direction from +800 mV were smaller than that in positive direction to +800 mV. It indicates that conductive polymers has never deposited on the electrode surface. These results suggest that the Au-ITO electrode, in which three-dimensional Au nano-structures are present in the form of islands, has a significantly larger effective electrode surface area for monomer oxidation than the ITO electrode. In particular, there is a large difference in the monomer oxidative potentials between Au-ITO and ITO. The value of the Au-ITO electrode is more negative (at least 200 mV) than the ITO electrode). By lowering the applied potentials for the electropolymerization of pyrrole in an aqueous solution, it is possible to suppress a degradation reaction such as hydrolysis occurring simultaneously with the polymerization reaction. Decomposition sites generated during the polymerization with positive potentials have a disconnection of π-conjugate structure, which probably accelerates the decomposition reaction in entire film.

3.2 Electrochemical Activity

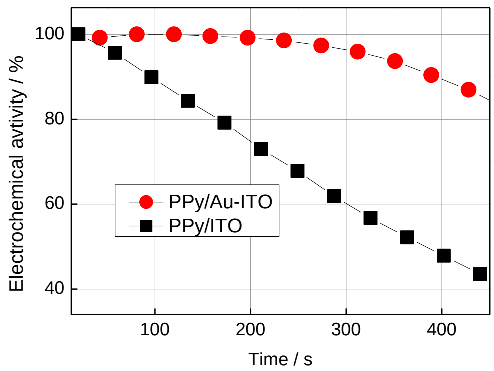

Fig. 3 Electrochemical stabilities of the PPy films on the Au-ITO or ITO electrodes for applied potential cycles.

In order to compare the decay in the electrochemical activity of PPy film on each electrode, continuous cyclic scans (50 mV/s) of the applied potential between -500 mV and +450 mV were carried out for the PPy films on each electrode in the polymerization solution. Fig. 3 shows the electrochemical activities of the PPy films for each cycle, where the activity value of 100% was the reduction current at 0 mV in the first cycle. In the case of ITO electrode, a continuous activity decay was observed from 2nd cycle. On the other hand, in the case of Au-ITO, the decay is suppressed up to 7th cycle. A significant difference in the stability was found between Au-ITO and ITO.

3.3 EC stability

As the demonstration of EC stability, fig. 4 showed a change in transmittance at a wavelength of 700 nm when continuous cyclic scans (50 mV/s) of the applied potential between -500 mV and +450 mV were carried out on PPy film immobilized on each electrode. For PPy films on both electrodes, the transmittance increased and decreased periodically due to redox reaction. In the ITO, the amount of change in transmittance had been reduced since the 2nd cycle. On the other hand, in the case of the Au-ITO, the amount of change was stable until the 7th cycle. In addition, subsequent decay (after 8th cycle) of the change was slower than that of ITO.

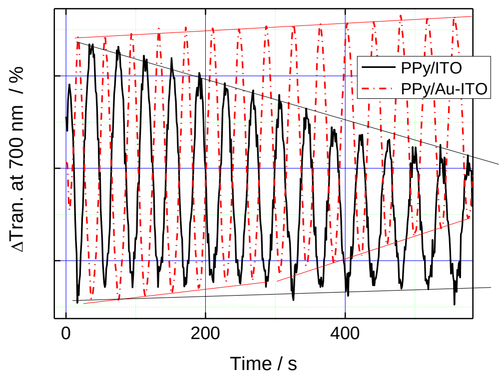

Fig. 4 Electrochromic stabilities of the PPy films on the Au-ITO or ITO electrodes for applied potential cycles.

The decomposition reaction seemed to be faster, probably because the aqueous solution was used as the electrolyte. About both electrochemical activity and EC stability, better results were obtained from the Au-ITO. It is concluded that the detachment of the polymer film is suppressed by the three-dimensional nano-structure existing on the ITO electrode surface.

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Scientific Research into the Green Metallic Luster of Safflower Red Pigment extracted by Traditional Method

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ABSTRACT

High quality safflower red pigment was extracted by an improved method of traditional one. The extracted pigment shows a green metallic luster in a dry state. In this project, this phenomenon was studied scientifically and the obtained results were expressed as a movie film.

1.INTRODUCTION

"Beni" is a pigment used for makeup such as lipstick, and is bright red. However, if "Beni" is applied thickly, the color becomes green with metallic luster instead of red. Since the late Edo period, makeup methods utilizing this phenomenon have been widely known. It is called "Sasabeni" and means shiny green like bamboo leaves, and can be seen in Ukiyo-e.

Almost at the same time in 1810, Johann Wolfgang von Goethe published “Theory of Color (Zur Farbenlehre)”. He described in the part 3 of the book, 578 of Chemical Colours, "A remarkable appearance may be here adverted to; pigments, in their deepest and most condensed state, especially those produced from the vegetable kingdom, such as the indigo just mentioned, or madder carried to its intensest hue, no longer show their own colour; on the contrary, a decided metallic shine is seen on their surface, in which the physiological compensatory colour appears.".

In modern Japan, there is a long-established store that deals almost exclusively with cosmetic “Beni”. They explain, "The red pigment is so pure that it absorbs red light and emits the opposite color, green light, so it looks iridescent in the dry state." As we can be seen from the expression of opposite color, Goethe “Theory of Color (Zur Farbenlehre)” has gained wide acceptance in traditional industries and the arts.

However, it is difficult to accept these explanations as it is from Newton's optical point of view that leads to modern science.

Then, we started the scientific research about green metallic luster of safflower red pigment after modification of traditional extraction method of the pigment. Since then 6 years were passed, we came to present the results as this film work today.

2. ABOUT THE FILM

Title: “Sasa color lipstick”（The Green Metallic Luster by Safflower Red Pigment） Prores422HQ 11 min.

Background： The previous our film produced in 2016 is remaining an unsolved matter, which the “Beni” shows greenish metallic luster in the dry state. This film is produced to reveal the mystery. The main production staff are the same as the previous work. The production method is also planned to be finished only with 35 mm film, and in fact, some scenes have been executed. The remarkable changes in the video production environment over the last few years have made it difficult to finish works only with film prints. As a result, it became hybrid work of film print and digital data.

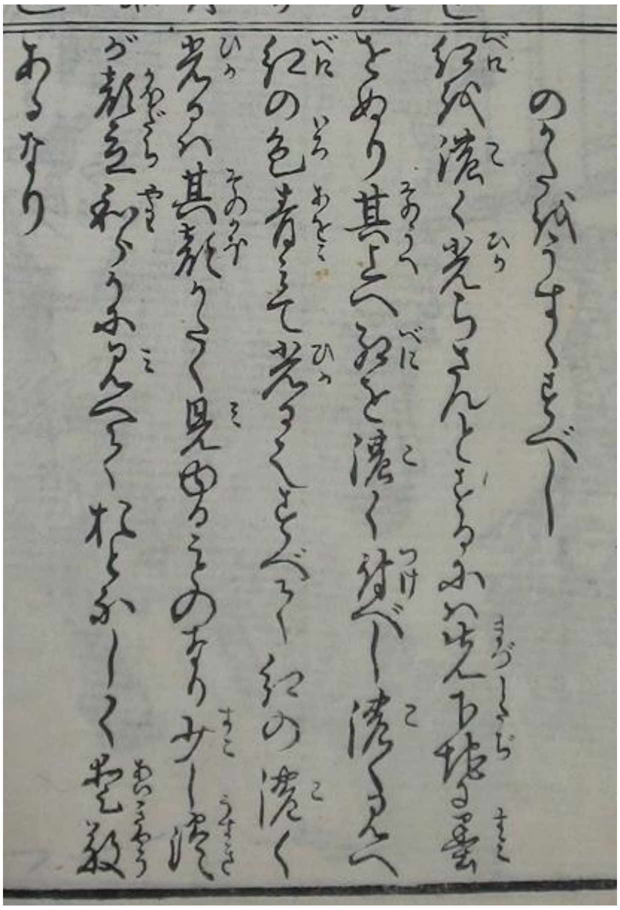

Fig. 1 Screen shot of “Miyako fūzoku kewai den”(Hanshichimaru Sayama).

3 . OVERVIEW OF THE FILM

Scientific considerations on the phenomenon that red pigment "Beni" produced from safflower has a green metallic luster when it is dried state.

Fig. 2 Safflower grown on Atsugi campus.

4. TARGET OF THE FILM

We assumed that high school students could understand.

5. HIGHLIGHT OF THE FILM

The "Beni" make-up scene, as operation manual written in the Edo period, show that the lower lip has a green metallic luster, and the bright red color of the upper lip is accompanied by red fluorescence.

6. STAFF OF THE FILM

Staring Momoka Endou
Music Yoshiharu
Director/Producer Hiroshi Yajima, Maiko Sasaki
Cinematography Hisoshi Nose
Cooperation
Kanazawa Institute of Technology
Nobeyama Radio Observatory
Hadano City
Pola Reserch Institute of Beauty&Culture

7. SCIENTIFIC BASIS OF THE FILM

This work is not commercial film, and is awareness film. All comments in the film are scientifically supported by journal papers as follows:

1. "Green Metallic Luster on the Film of Safflower Red Pigment Extracted by a Traditional Method -Approach with Optical Measurements-" Hitoshi Yajima, Maiko Sasaki, Keiko Takahashi, Kazuyuki Hiraoka, Masato Oshima, Katsumi Yamada, J. Soc. Photogr. Sci. Technol. Jpn., (2018), Vol.81, 65-69
2. " Influence of Photo-illumination on Greenish Metallic Luster of Safflower Red Pigment Film" Hitoshi Yajima, Maiko Sasaki, Keiko Takahashi, Masato Oshima, Kazuyuki Hiraoka, Morio Yashiro, Katsumi Yamada, Bull. Soc. Photogr. Imag. Japan. (2018), Vol. 28-2, 18-22.

Fig. 3 Screen shot of "Beni".

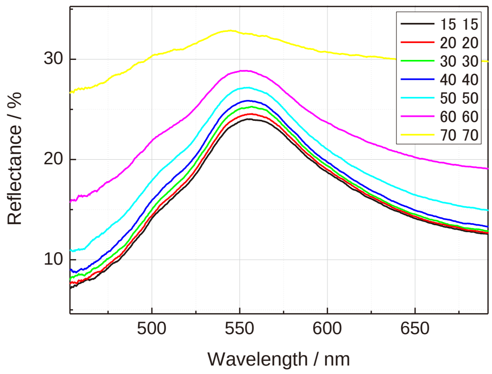

Fig. 4 Specular reflection spectra of safflower red pigment film ("Beni") on the black base. Incident angle and reflected angle were 15° - 70° and 15° -70° for surface normal, respectively.

Fig. 5 Screen shot of green metallic luster of "Beni".

Accuracy Verification for Self-Localization Depending on Color Calibration Skill

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ABSTRACT

We developed a self-localization technique using an omnidirectional camera for an autonomous soccer-playing robot. Positional information is important for the robot's strategic behavior and cooperation. We developed a self-localization method, which uses the white lines on the soccer field to generate a search space model, and a fitness function in a genetic algorithm (GA) to identify the robot's position on the pitch. We conducted an experiment to verify the accuracy of this method and confirmed the difference in positional accuracy by using team members who adjust the parameters for color detection.

1. INTRODUCTION

RoboCup's main research goal is to study how multi-robot and multi-agent systems engage and cooperate with each other in dynamic situations, through the game of soccer [1]. On the RoboCup soccer field, robots use self-localization to estimate their own position, as well as the positions of the goals and other robots. They then use this information to decide on a strategy. The robot uses image information, environment information, and field information. In this paper, we describe a real-time self-localization method that applies a genetic algorithm (GA) for the RoboCup middle size league (MSL), which has the largest field (12 x 18 m).

2. Hardware structure

We developed a robot with recent MSL technology: a high-torque-driving module, ball-control module, electrical kicking module using a solenoid, and USB 3.0 camera system.

The omnidirectional vision system (Fig. 1) of our robot consisted of a FLIR Flea3 camera, Vstone varifocal lens, and Vstone hyperboloidal mirror. An image captured by this vision system is shown in Fig. 2(a), and the image size and frame rate are 512 x 512 pixels and 30 fps, respectively.

3. Self-localization method

The robots use the white lines on the MSL field for self-localization. We developed a self-localization method that uses model-based matching to generate a search space based on the white line information from the soccer pitch. It then uses the fitness function to express the robot's correct position as the maximum value of the function. The self-localization method uses a GA [2] to optimize the fitness function.

Fig. 1. Mechanical layout of our robot

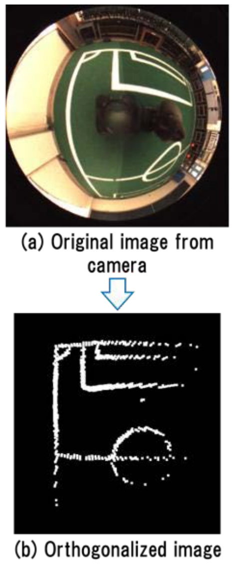


Fig. 2. Process of making search model

3.1 Search model

Figure 2 shows the process of making the search model with our method. We obtain the white detection image by converting the color space from RGB to HSV and YUV, and we generate the field information by orthogonalizing the white line information, as shown in Fig. 2(b).

3.2. Model-based matching

Our self-localization method uses model-based matching to compare geometric information from the white lines on the MSL field and the search model to generate the search space. Let us denote the set of pixels that compose the search model shown in Fig. 3, as S_f. The position $\tilde{r} = (\tilde{x}, \tilde{y})$ and orientation $\tilde{\theta}$ of the search model in the image are represented as $\tilde{\varphi} = [\tilde{x}, \tilde{y}, \tilde{\theta}]^T$. Then the movement of S_f in the matching area is expressed as $S_f(\tilde{\varphi})$. By denoting the pixel value of the field image corresponding to the area of the moving model as $p(\tilde{r})$, $\tilde{r} \in S_f(\tilde{\varphi})$, the evaluation function $F(\tilde{\varphi})$ of the moving model is given as follows.

$$F(\tilde{\varphi}) = \sum_{\tilde{r} \in S_f(\tilde{\varphi})} p(\tilde{r})$$

The fitness function $F(\tilde{\varphi})$ obtains the maximum value when the position of the search model corresponds to the same position as the robot on the MSL field. The problem of detecting the robot's position and orientation is converted to a search problem of $\tilde{\varphi}$ such that $F(\tilde{\varphi})$ is maximized [3].

3.3 Genetic algorithm

In our self-localization method, we use a GA to find the maximum value of the fitness function $F(\tilde{\varphi})$. GAs are a type of artificial intelligence and are parallel search-and-optimization processes that mimic natural selection and evolution. We use an elitist model to preserve the best individual in the population in every generation, genetic coding by gray code, roulette selection and one-point crossover. The parameters of the GA process are determined by previous experiments.

3.4 Verification

We performed an experiment to verify the effectiveness of the proposed self-localization method. Figure 4(a) shows the error between the correct position and the detected position in a quarter of the MSL field at an interval of one meter. The severity of the error is indicated by the brightness of the gray scale. The average error was 13.5 cm, so the self-localization method is accurate enough for playing soccer.

Figure 4(b) shows another experimental result in the same situation for another team member who does not have enough color calibration skill for self-localization, i.e., a beginner team member. The average error was 38.7 cm, and the maximum error was 866 cm. These results mean that the robot sometimes does not recognize the position correctly.

Figure 5 shows the search models of each experiment. The search model of Fig. 5(a) generated by a specialist who is experienced in color calibration for this task can express the white line shape of the pitch well. However, the search model of Fig. 5(b) generated by a beginner expresses only part of its shape because the parameter set for color detection is not suitable in this experimental environment. In this case, the parameters, especially the parameters for detecting green, were incorrect.

4. Conclusion

In this paper, we described a self-localization method that generates a search space using model-based matching combined with white line information from the RoboCup MSL soccer field. It calculates the position of the robot by using a genetic algorithm to optimize the fitness function. We verified the effectiveness of the self-localization method and confirmed that it is accurate enough for playing soccer.

Moreover, we also verified the difference in accuracy of self-localization between specialist and beginner. We confirmed that its accuracy is completely different depending on color calibration skill.

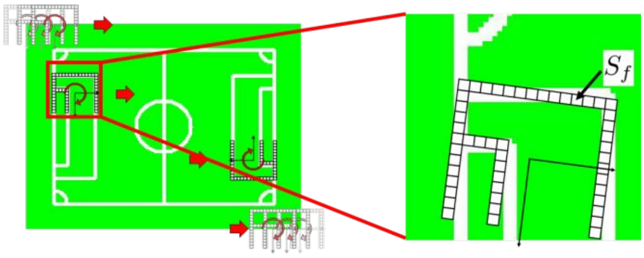
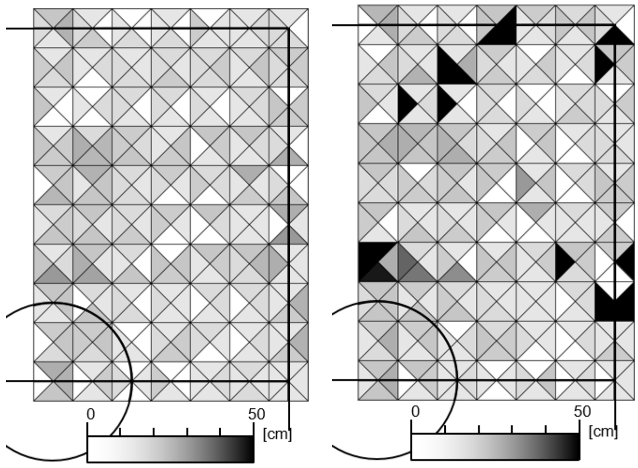


Fig. 3. Model matching



Maximum error cm	40
Average error cm	13.5

(a) Specialist

Maximum error cm	866
Average error cm	38.7

(b) Beginner

Fig. 4. Self-localization error

(a) Specialist (b) Beginner

Fig. 5. Search model

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Color Perception of Naturalistic Objects and Faces

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ABSTRACT

Our visual system can adapt to various changes in the color environment and maintain a stable color appearance (e.g., color constancy). The combination of multiple cues presents within objects and surroundings in a natural three-dimensional scene should contribute to color constancy. However, specular highlights would have only a little contribution. Face and skin are essential natural stimuli in our life. It has been suggested the existence of color perception specific to facial skin. We showed that reddish skin appears brighter than yellowish skin for Japanese observers, but our international comparison implies that various factors may also influence facial color perception.

1. INTRODUCTION

Our visual system can adapt to various changes in the color environment and maintain a stable color appearance. Color constancy is one of perceptual property, showing that we perceive the stable color of objects even if the reflected light changes depending on illumination color [1].

To understand color constancy in real life it is essential to conduct experiments within real three-dimensional (3-D) space. Color constancy is generally better and more stable for 3-D stimuli compared with two-dimensional (2-D) stimuli. We showed that monocular viewing with limited view and motion parallax designed to make a 2-D scene appear more like a 3-D scene improved color constancy in the image [2]. This suggests that the combination of various cues present within the object and environment, and the recognition of space, illumination and objects, should contribute to establishing good and stable color constancy.

Face and skin is also one of most important natural stimuli in our life, and skin color is essential for obtaining various information on our body and mind, such as health, age, and face impression. Therefore, we must have developed visual sensitivity tuned to skin. It has been suggested the existence of color perception specific to facial skin. For example, it has shown that sensitivity to changes in reddish direction of the skin is better than other color directions. Reddish skin looks brighter than yellowish skin even if they have the same lightness [3].

Here, I introduce two topics on color perception on naturalistic stimuli. The first topic is the influence of surface property on color constancy for familiar objects. The second topic is an international comparison of the brightness perception of facial skin.

2. INFLUENCE OF SURFACE PROPERTY ON COLOR CONSTANCY

2.1 Objective

One of the critical factors influencing color constancy would be the richness of cues. It has been in discussion on the contribution of specular reflection occurring on the glossy surface of an object because different researches showed contradictive results. This contradiction would be due to a difference in stimuli and viewing conditions. Here, we examine the effect of the surface and specular reflection of objects on color constancy using vegetables as familiar objects in real space.

2.2 Experiment

We built a booth arranged like an ordinary room illuminated by either whitish or reddish. We used three types of familiar vegetables as stimuli. They had a surface with two gloss types: a gloss and a matte surface. Figure 1 shows the stimuli used in the experiment. An elementary color naming method was used for evaluation. Normal view and limited view conditions were tested. In the limited view condition, observers viewed a stimulus only through a tube.

Observers evaluated stimuli with different glossiness under white and reddish color illumination, and we compared those color appearances.

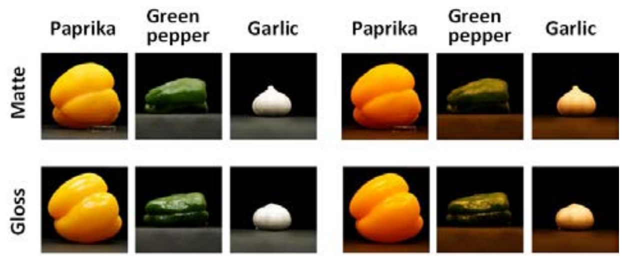

Fig. 1. Stimuli under the white and reddish light

2.3 Results

Figure 3 shows the response shift showing the intensity of color constancy under each condition. Color constancy is higher in the normal view condition than the limited view condition. Color constancy is stronger for the gloss surface than the matte surface. This trend is more apparent in the limited view condition. The results showed that while specular highlights barely contribute to color constancy under a normal viewing condition with real 3-D objects in the real 3-D environment, a small contribution was observed under limited viewing condition, under which only an object was observed in isolation, without any surrounding information.

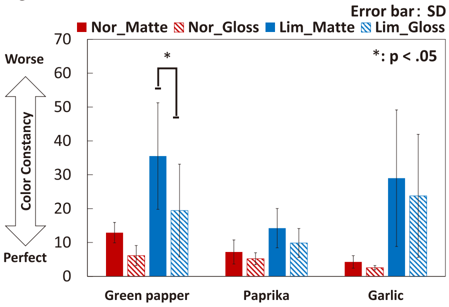

Fig. 2. Strength of color constancy (perceptual color difference in white and reddish light)

These results imply that a specular cue for color constancy would be revealed only under specific conditions in which other cues, such as surroundings and object shape, are not available, and the highlight region is recognized as a specular component. The contribution of specularity to color constancy may be buried under conditions that include other rich cues for illumination.

3. BRIGHTNESS PERCEPTION OF FACIAL SKIN

3.1 Objective

The skin color distribution of young Japanese women measured with a colorimeter showed a trend that yellowish skin had higher lightness compared to reddish skin. On the other hand, it was shown that reddish skin appeared brighter than yellowish skin when both had the same lightness [3]. However, the previous result was obtained from the experiments using Japanese faces with Japanese skin color and for Japanese observers. Skin color varies among different ethnic groups, from dark to light, and from yellowish to reddish. It is not clear how the brightness perception of facial skin is influenced by the diversity of skin face colors and observers. Here, we investigate the brightness perception of facial skin for Japanese, Thai, and Chinese observers.

3.2 Experiment

We used a young Japanese female face, which was an average of forty female faces. We prepared test faces with four skin color types that were the average skin color of Japanese, Thai, Caucasian, and African. Figure 3 shows an example of stimuli with Japanese skin color. The skin color of each face was modified by changing the ratio of L*, a*, b* from each test face. Test images with constant lightness and different hue angles were generated. Scale images had the same hue angle corresponding to an original face color of each skin color type and different lightness. A test image and a scale image were presented side by side on a color-calibrated tablet display. Observers adjusted the lightness of facial skin on the scale image to match the brightness of the test image with the scale image. They evaluated four groups of stimulus images, three times each. We conducted experiments in Japan and Thailand.

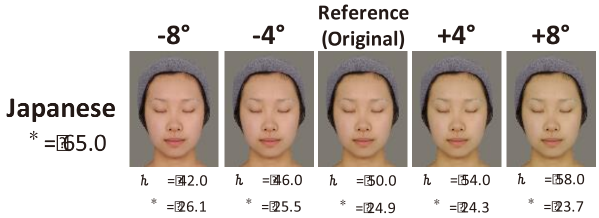

Fig. 3. Example of modulated images (Japanese)

3.3 Results

As shown in Figure 4, Japanese observers showed a trend that reddish skin appeared brighter than yellowish skin, consistent with the previous study. In contrast, Thai observers showed an opposite trend, and Chinese observers did not show the systematic influence of hue. They suggest diversity in the brightness perception of facial skin.

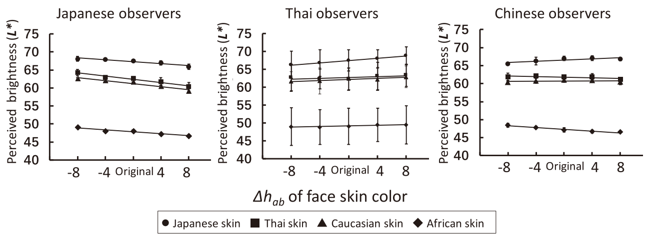

Fig. 4. Results of brightness perception of Japanese, Thai, and Chinese observers

4. CONCLUSION

It is important to investigate color perception for natural objects in the natural environment. The combination of various cues in objects and environments would contribute to stable color perception. However, the weighting of each cue would be different, such as a small contribution of specular highlights. Face and skin are also important natural stimuli in our life, and we would have color perception specific to facial skin. An international comparison of brightness perception of facial skin implies that various factors such as facial color distribution, ethnicities, environments, and cultures may also influence facial color perception.

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[3] H. Yoshikawa, K. Kikuchi, H. Yaguchi, Y. Mizokami, and S. Takata, “Effect of Chromatic Components on Facial Skin Whiteness,” Color Research & Application, 37, 4, 281-291 (2012)

Expanded Global Activities through Exhibitions of col.lab Exhibits and Branding Research at Oversea Museum

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ABSTRACT

Color is closely related to photography, printing, and optics, which have been research fields of TPU since its foundation. Color is also one of the fundamental elements of art. In such a background, In such a background, our project have held between exhibition including workshop. and research of scientific view point. Since the category adopted by the University is Type B (global development type), some of the above activities will be introduced and exhibited at museums overseas. Specifically, the representative activities were exhibited at the Emile Kreuz-Seder Museum (Municipal) in Finland. Furthermore, in the foreign country of Finland, we took care to convey Japanese culture from the viewpoint of art and engineering from the ancient tradition of Japan, "BENI".

1. INTRODUCTION

This year marks the fourth year since the university's branding activities began. Up to now, the exhibition at the "col.lab" gallery has been diversified and continued once every six months while changing the exhibits. We are also working on less than 20 themes in our research.

In this presentation, we will introduce the expanded global activities through exhibitions of **col.lab** exhibits and branding research at museum of Finland.

2. Exhibitions and workshops at museums

Emile Kreuz-Seder Museum. is classified as an Art and Cultural Museum, found in 1916, It is located about 200 km northwest of Helsinki. and is now managed by the city of Harjavalta, Finland. Fig.1(a) and (b) shows photograph of the entrance of the museum and (b) aerial photograph, respectively. From May 5 to September 8, 2019, the museum exhibited under the theme "Japonism Today."

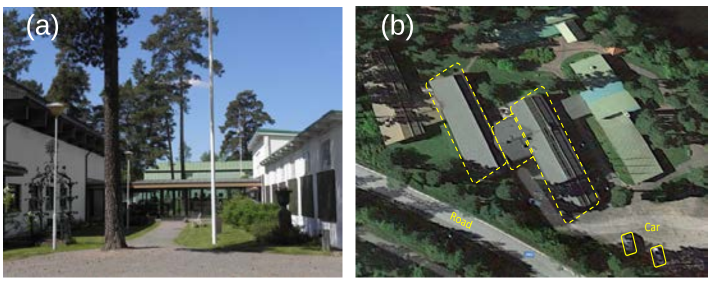


Fig.1 (a) A photograph of the entrance of the museum and (b) Aerial photograph

So far, the following three representative works that have been exhibited at the university's **col.lab** gallery and the explanation of this project have been exhibited and workshops in a room in a museum. A flyer for this event as shown figure 2 was prepared in English and Finnish.

Exhibition are 1) Movie of "BENI" was screening (Finnish subtitles) and demonstration by Assoc. prof. Yajima, 2) Interactive camera demonstration of famous painters paint style called as "AI mirror" provided by Prof. Kuhara,3) Three kinds of large optical illusion color mixing cubes called as "CMY Cube" was presented by lecturer Miyazaki.

Fig.2 Flyer of TPU exhibition and symposium in Emile Kreuz-Seder Museum in Finland

Fig.3 Photograph of (a) BENI(safflower) movie screening and (b) workshop on color extraction and dyeing from safflower. Inset fig is demonstration of workshop.

Figure 3 shows the movie of "BENI", which was shown to the general public people, elementary and junior high school students, and Japanese people living in Finland.

For this screening, subtitles were included under the supervision of a Finnish translator and a dyeing researcher. As a result, works that convey Japanese culture, which has a reputation in Japan, could be promoted to foreigner.

Fig.4 Photograph of Pamphlet. Black card is free sample of "BENI" distributed to participants.

Free sample of "BENI" distributed to participants as shown in Fig.4 . High quality "BENI" indicates a shining green color instead of red as shown in the Fig.4 as on black card.. By adding a little water to it, it shows a bright red color. In this workshop, participants were able to experience these phenomena myself by using distributing samples. As the results, It was very reputable.

Participants of this event were not only general Finnish but also elementary and junior high school students and Japanese tours, and their ages and fields were diverse. About 300 color samples were distributed at the "BENI" exhibition, and a considerable number of visitors were obtained at this exhibition in only 3days.

Fig.5 Photograph of interactive camera demonstration of famous painters paint style called as "AI mirror".

Fig.6 Photograph of three kinds of large optical illusion color mixing cubes called as "CMY Cube

Fig.5 shows an interactive camera demonstration of famous painters paint style called as "AI mirror". This exhibition was very well received because each participant's face projected by a camera looks like a picture of a famous painter.

Three kinds of large optical illusion color mixing cubes called as "CMY Cube is shown in fig.6. The exhibition of the CMY cube was also pick-up in a two-page spread in a local newspaper (SATAKUNNAN KANSA[1)], in Finland).

3. Collaboration between Technology and Art

On of the aim of the TPU branding project is promoting to further collaboration between technology and art on color.

According to this philosophy, The roots of this project, "BENI", which won an award in the artistic cinema area, have made further progress in the activities of this project. It has been successful in scientific research on the mechanism of red coloring, and as a result has been awarded 2019 best paper award of the society of photography and imaging of japan which was entitled “Green metallic luster on the film of safflower red pigment extracted by a traditional method -Approach with Optical Measurements-”..

In the case of CMY Cube, The difference in the appearance (color) of the CMY cube depending on the direction of light incidence is verified by using a lighting dome as shown in fig.7(a) and also shown numbering of lighting source as shown in fig 7(b)

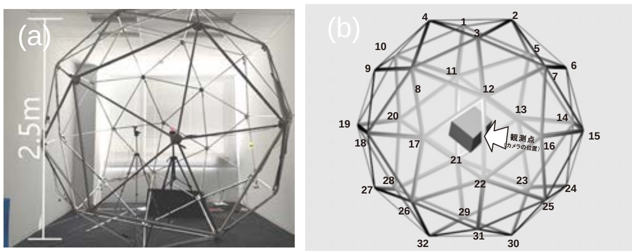
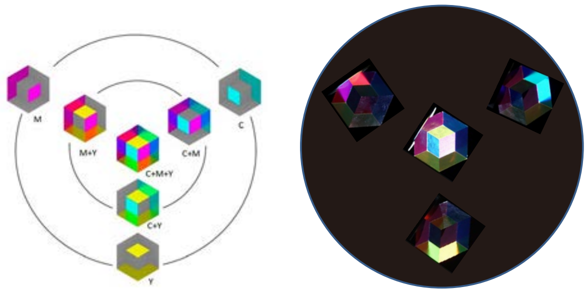


Fig.7 (a) Shape of lighting dome and (b) numbering of lighting source.



Color Indication on CMY cube

(a) Theoretical (b) Experimental by using lighting dome

Hence, through the exhibits and branding research on the color successfully make the faculties of Engineering and Arts can both conduct studies , which will lead to further collaboration between technology and art for world wide.

1) Satakunnan Kansa is a Finnish language regional newspaper published in Pori, Finland.

2) T.Yajima, M,Sasaki, K.Yamada *et.al,* 2019 Best Paper Award of the The Society of Photography and Imaging of Japan.

International collaborative research and art production on TOKYO 2020 theme colors “Crimson”, “Indigo”, and “Kasane no Irome”

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A group of faculty members from Tokyo Polytechnic University (TPU), Coimbra University (Coimbra), and IADE, Creative University, are doing collaborative research and art production on TOKYO 2020 Olympic Games theme colors “Crimson”, “Indigo”, and “Kasane no Irome.” Producted works will be presented at art exhibition events both in Japan and Portugal as part of 160th Japan and Portugal's diplomacy anniversary activities supported by Embassy of Japan in Portugal.

Their joint work goes back to 2007, and many of the faculty members, undergraduate students, and graduate students from these three schools have participated in the activities and produced art works. Based on such achievements, the current TPU faculty members are again working with Coimbra and IADE partners on research and production plans on the theme of “color”.

TPU members first did historical study of traditional Japanese color, “Kasane no Irome”, which is the theme color. Based on the finding from this study, they have given lectures and workshops at Coimbra and IADE, and now they are examining the differences in color expression among different cultural groups with Coimbra and IADE members. They use various methods of media art, such as animation and interactive art for the productions.

One of the planned outcomes of this collaborative project is to disseminate the result media art works of faculty members and their students in both Japan and Portugal and show them internationally. School facilities and outside galleries in Japan and Portugal will be used for the art exhibitions and presentations of research findings. We also plan to hold lectures and workshops based on this research. At the same time, we will participate in the 160th Japan and Portugal's diplomacy anniversary events sponsored by the Embassy of Japan in Portugal to contribute to the exchange between the two countries.

First attempt

In December 2019, Yukio Yamanaka, TPU faculty, gave a lecture at the Faculty of Engineering of Coimbra University. The title was “TOKYO 2020 and Kasane no Irome”. There, he explained about cultural significance of “Crimson” and “Indigo”. It showed the reason why they have selected these theme colors for the 2020 Tokyo Olympic Games. In addition, Yamanaka introduced the core graphic, “Kasane no Irome” and explained “the sense of Japan” produced by “color”. In the lecture, Yamanaka talked about “24 seasons” in Japanese calendar and way of grasping detailed sense of seasonal changes. A sense of color was linked to this sense of seasons, creating a culture of using various color combinations and names. Kasane's color scheme became a method of expressing the meaning of status, celebration, contraindications by overlapping multiple colors. The TOKYO 2020 Olympic Games theme colors “Crimson” and “Indigo” and Core Graphic, “Kasane no Irome” have been selected as symbols that represent this unique way of capturing colors in Japan.

An animation production workshop was held the next day presented by Yukio Yamanaka, Kei Suyama, and Masamichi Okubo. In this workshop, participants created short animations using the time-lapse technique by combining pieces of colored paper and line drawings, and they gained the new understandings on animation production. As a result of this workshop, a 12 of short video clips were completed by 12 participating students, and the clips were edited into one video production. The completed animation work was shown on a screen at the end of the workshop.

Second attempt

We have planned the next workshop based on the first lecture and workshop. Lecture "Media as Colors" in February 2020. Testu Kondo, another TPU faculty, shares creative ideas and perspectives as he shows his personal art productions and various types of projects with media technologies. After the lecture, a workshop “Creative art and media workshop” will be held. The purpose of this workshop is to let students with various backgrounds collaborate and create art works with strong concepts. Discussion and concept building will be the most important rolls for this workshop. They pick up any media to express their ideas based on concepts of “Color”. Workhop proceeds through the steps of Brain Storming, Concept and philosophy building, and Technical Approach. In this production, we plan to use the animation video produced in the first workshop. The goal of the outcome is Exploring our artistic idea and aesthetic of "Color" with technology.

These two types of lectures and workshops are also given to students and graduate students of Tokyo Polytechnic University, and finally summarize the products of both universities, Exhibition opportunity in 2021 at Collabo gallery in Japan.

What is “color”?

Students, graduate students, and faculty members from both Japan and Portugal will be asked to consider “What is ‘color’ for me?” and express it in various media art forms using the TOKYO 2020 theme colors “Crimson”, “Indigo” and “Kasane no Irome”. The works will be shown at exhibitions in both Japan and Portugal as we have mentioned in the plans.

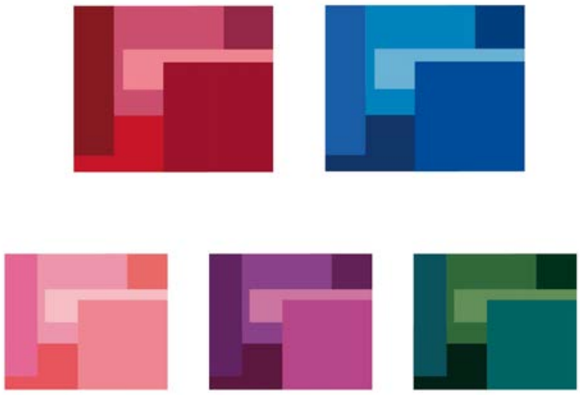

Fig.1 ”CRIMSON,INDIGO and color chart /TOKYO2020 official web site"
https://tokyo2020.org/jp/news/notice/20180817-02.html

Fig.2 Photograph of one of workshop on international collaborative research

Fig.3 Photograph of one of lecture on international collaborative research

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3月13日（金）　タイムテーブル・目次

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