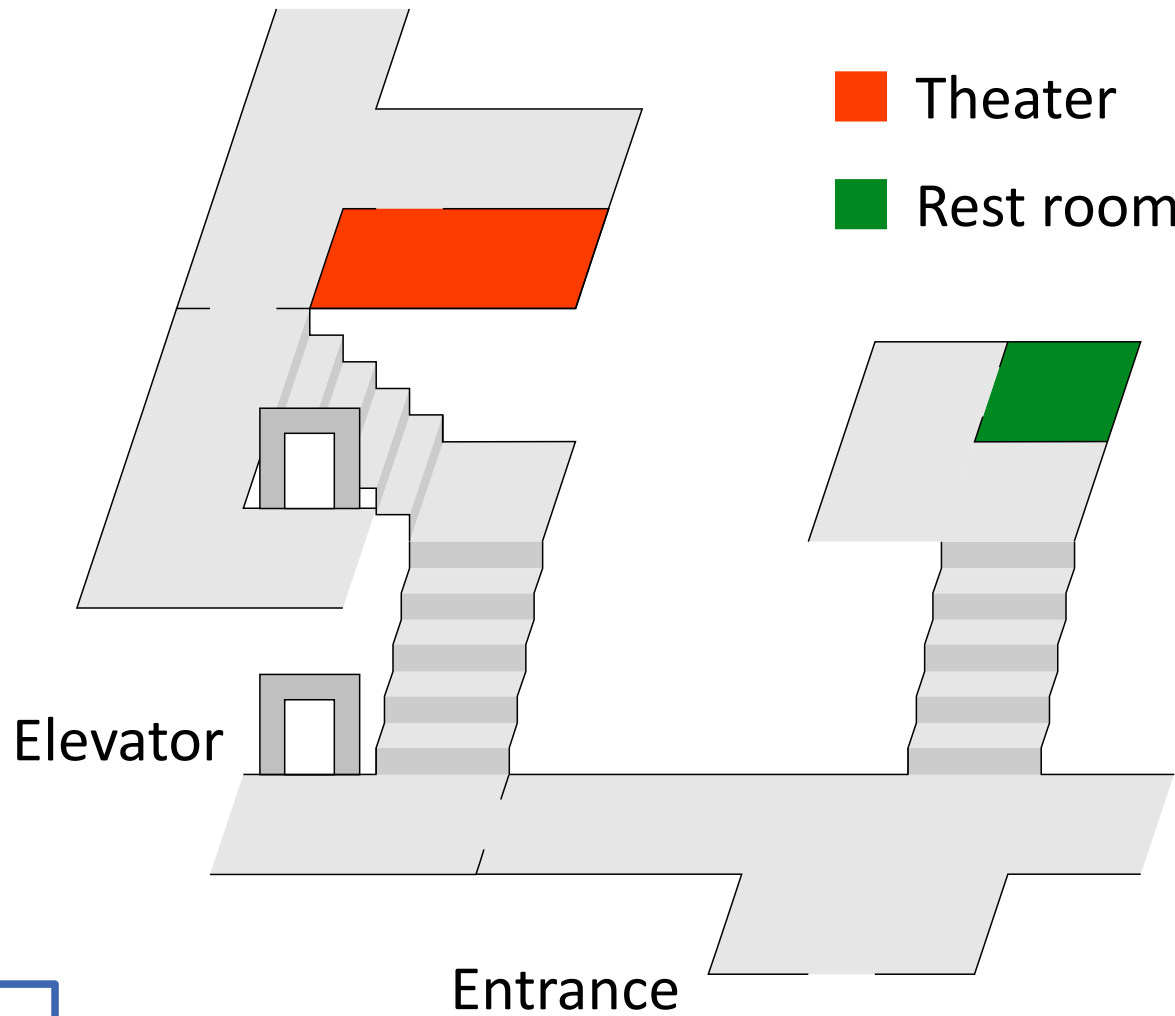# Automatic Color Scheme Adjustment for Different Color Vision
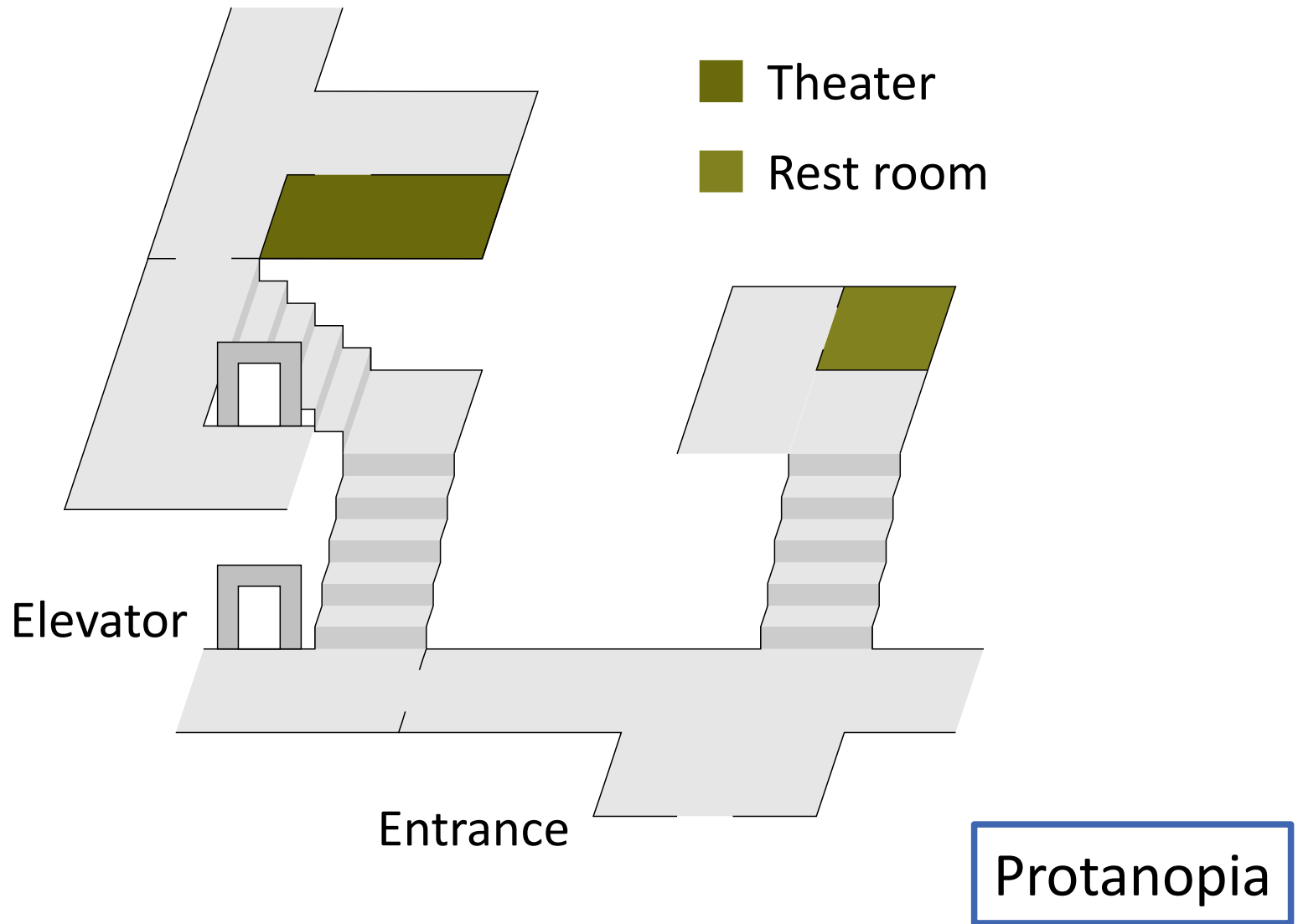
Takuto Yanagida and Hidenori Mimura
Research Institute of Electronics, Shizuoka University
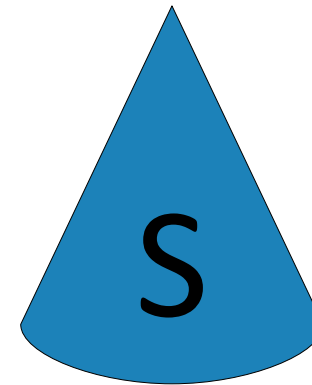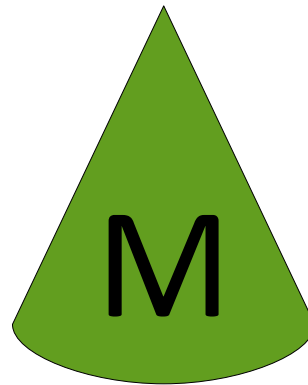
Which is the theater?

Theater

Rest room

Elevator

Entrance

Trichromacy

Which is the theater?

Theater

Rest room

Elevator
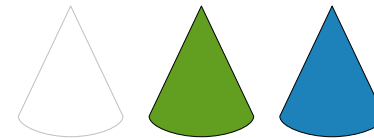
Entrance

Protanopia

Color vision

- **Cone cells** on retinas in eyes
  - **L** types for long wavelength
  - **M** types for medium wavelength
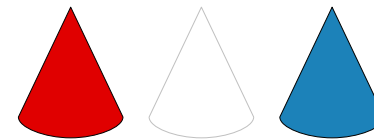 - **S** types for short wavelength
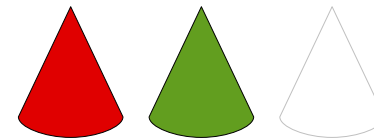
Color vision deficiency

- Dichromacy

  - Protanopia (protanomaly)

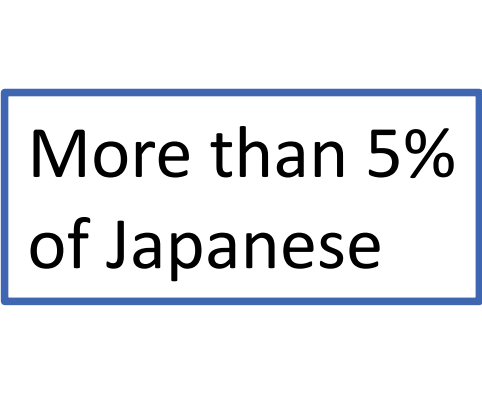 - Deuteranopia (deuteranomaly)

  - Tritanopia (tritanomaly)

† Protanomaly, deuteranomaly, and tritanomaly are color vision deficiencies caused by mutated cone cells, and in this work, they are included in protanopia, deuteranopia, and tritanopia respectively.

Color vision deficiency

- Dichromacy

  - Protanopia (protanomaly)

  - Deuteranopia (deuteranomaly)

  More than 5% of Japanese

  - Tritanopia (tritanomaly)
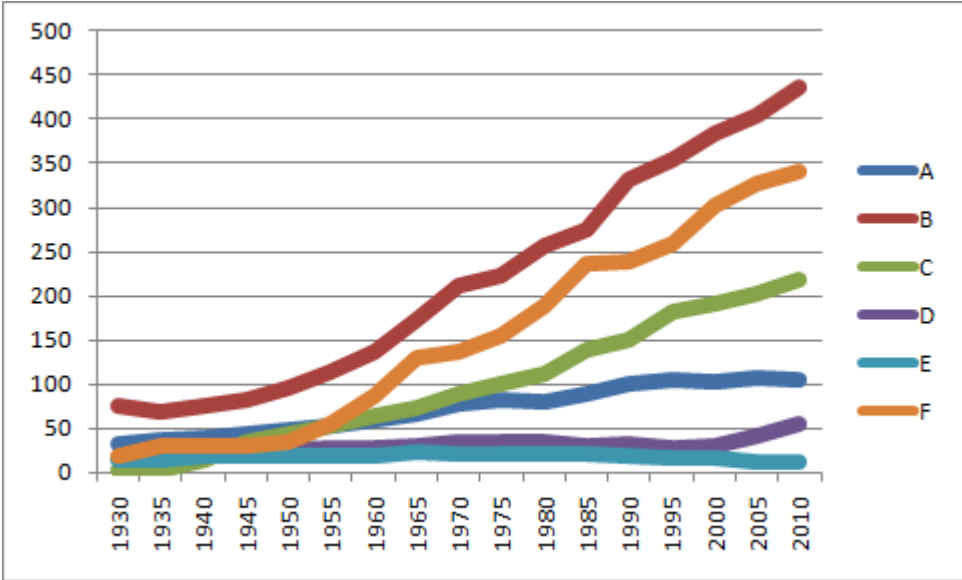
Purpose of this work

- Developing a tool for adjustment of color scheme:

    - To enlarge color differences in different color visions

        – Trichromacy   (type **3**)

        – Protanopia   (type **P**)

        – Deuteranopia (type **D**)

    - To maintain the original color scheme as possible
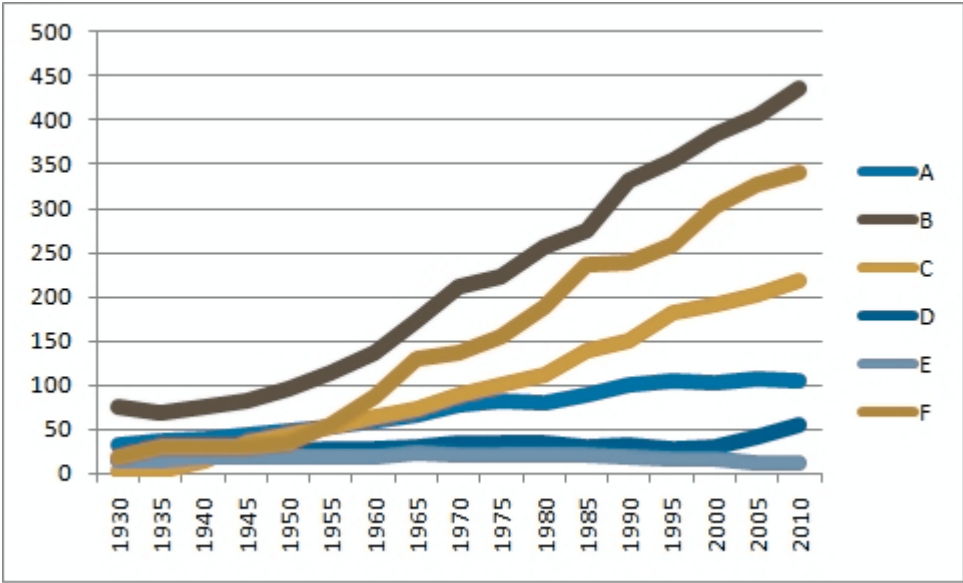
> For 'color universal design' and 'art design'
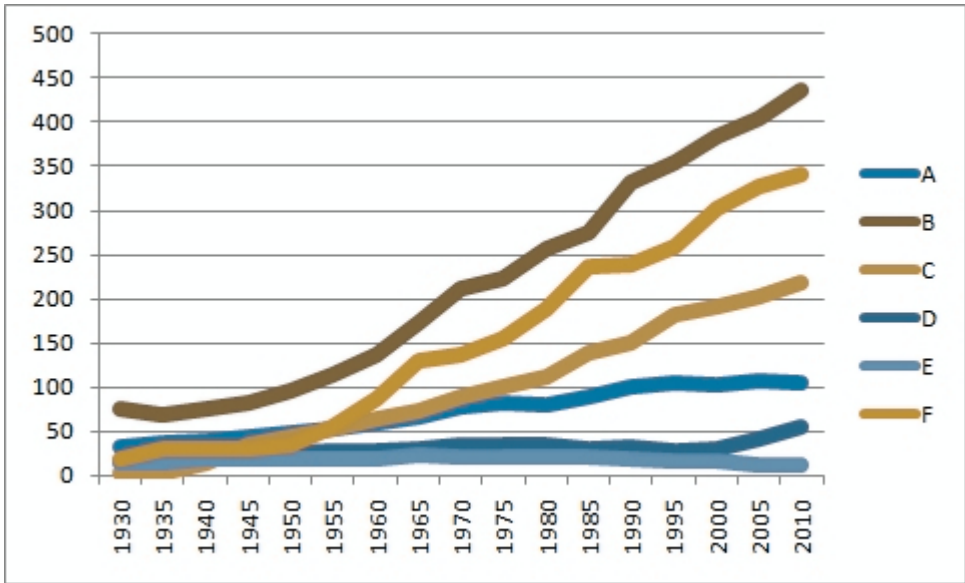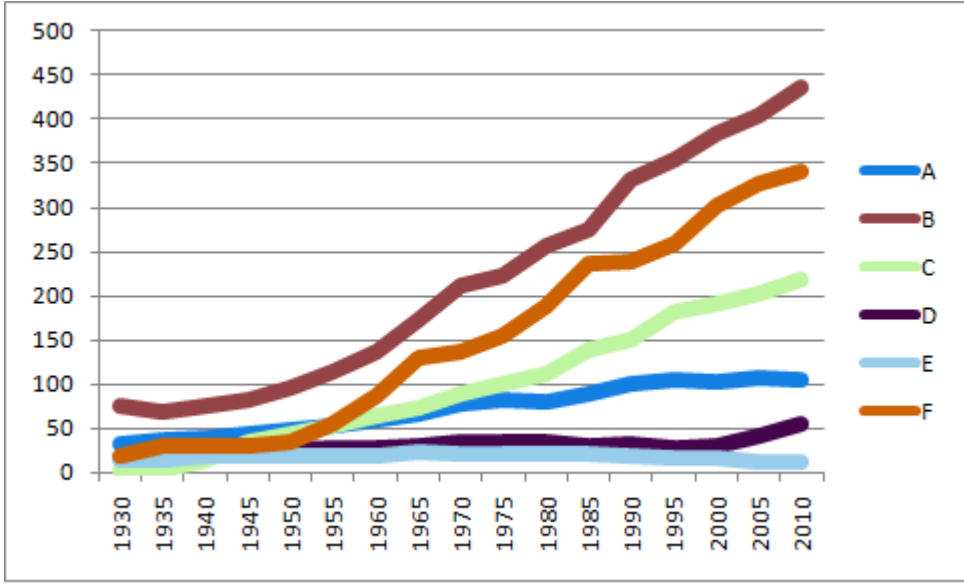
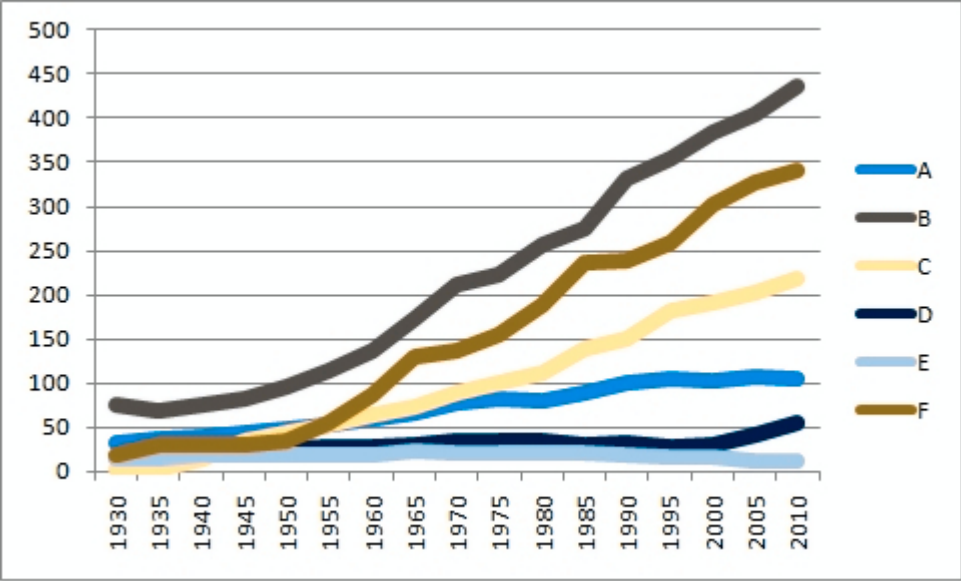Before — Type 3

Type P

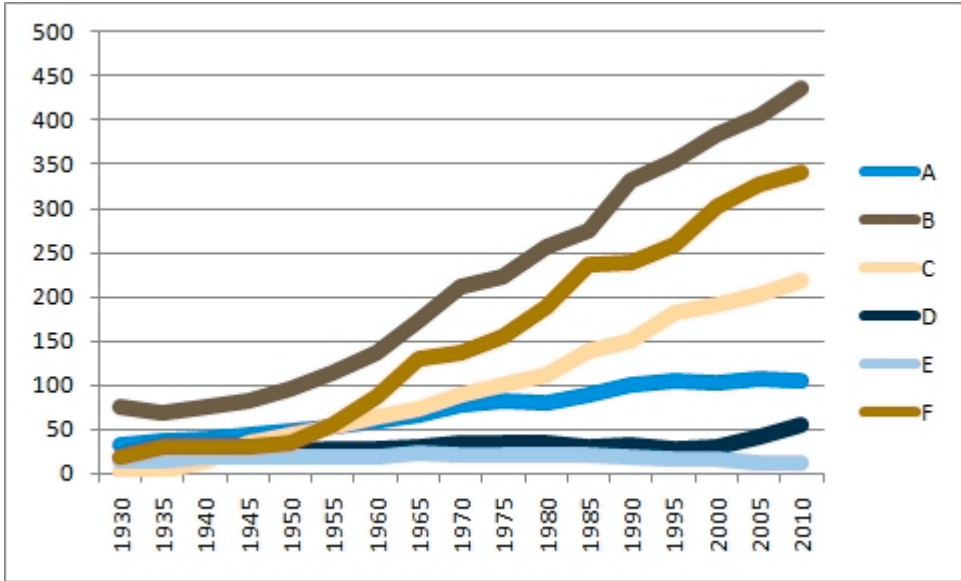Simulations

Type D

8

After — Type 3

Simulations

Type P

Type D

9

How to handle the problem?

- A color is a **combination** of parameters, brightness, chroma, and hue

- A color scheme is a **combination** of colors

- **How to find a color combination**

  - which are different enough,

  - while maintaining the original colors?

Applied technology

- **Fuzzy constraint satisfaction problem (FCSP)**

    - A field of artificial intelligence

    - A framework of **combination search problems** of assignments that **almost** satisfy constraints among variables

    - General-purpose **solvers** are proposed

† Ruttkay, Z.: Fuzzy Constraint Satisfaction, Proceedings of the 3rd IEEE Conference on Fuzzy Systems, Vol. 2, USA, pp. 1263–1268 (1994).

Fuzzy constraint satisfaction problem (1)

- Variables
  - $X = x_1, ..., x_n$ Expressing **solution** by assigned values

- Domains
  - $D = D_1, ..., D_n$ Sets of values possible to be assigned

- Constraints
  - $C = c_1, ..., c_r$ Rules of possible combinations of values
    - with **satisfaction degrees** (desirability of combinations)
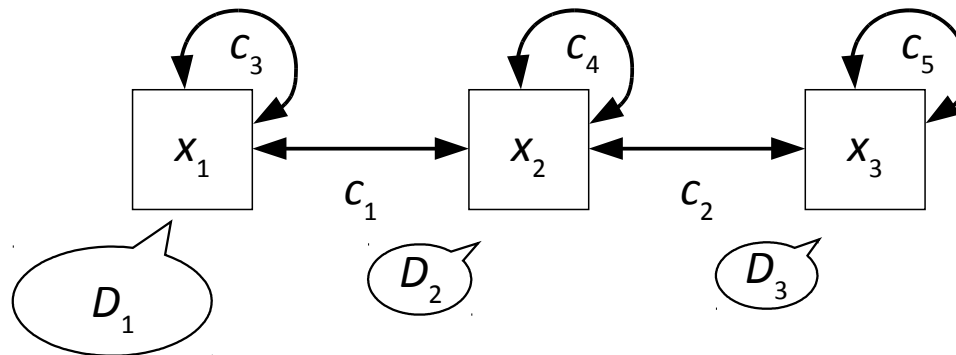
Fuzzy constraint satisfaction problem (2)

- Solutions
  - **Assignments of all variables**
    - with satisfaction degrees (0, 1]
    - The minimum of all satisfaction degrees:
      - $C_{min}(v) = min(\mu R_h(v[S_h]))$
      - Assignment v is a solution when $C_{min}(v) > 0$

Formulation

- Color (variable)

  - A color selected from a palette

- Palette (domain)

  - A set of neighbor colors and the original color

  - The range of neighborhood is defined by conspicuity

- Relation of colors (constraint)

  - Color difference in each color vision

  - **Expressing desirability as satisfaction degrees**

Domain

- Colors on concentric spheres In CIE 1976 L*a*b* color space

    - The center is the original color

    - Their radii increase by Δr
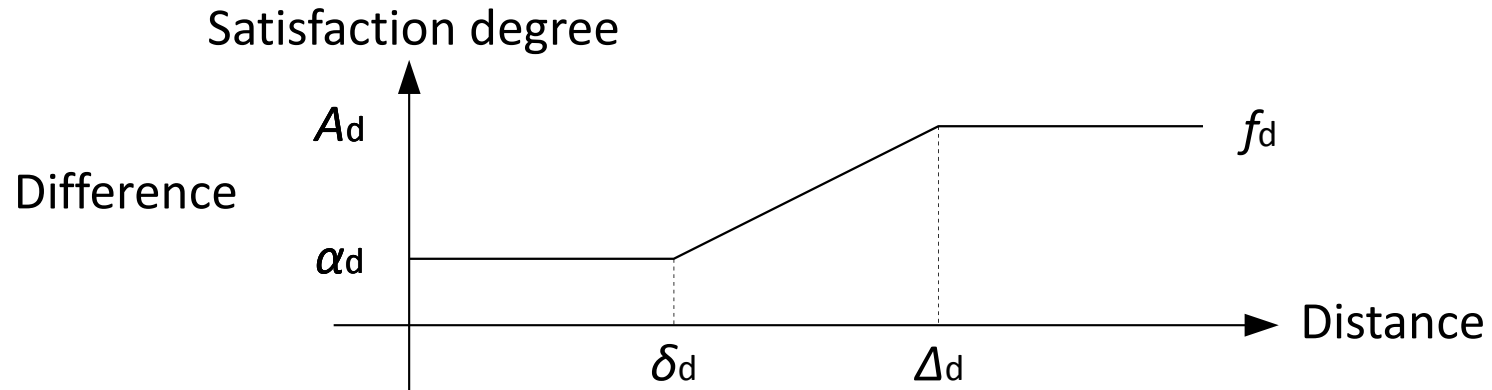
   - Higher conspicuity makes smaller Δr
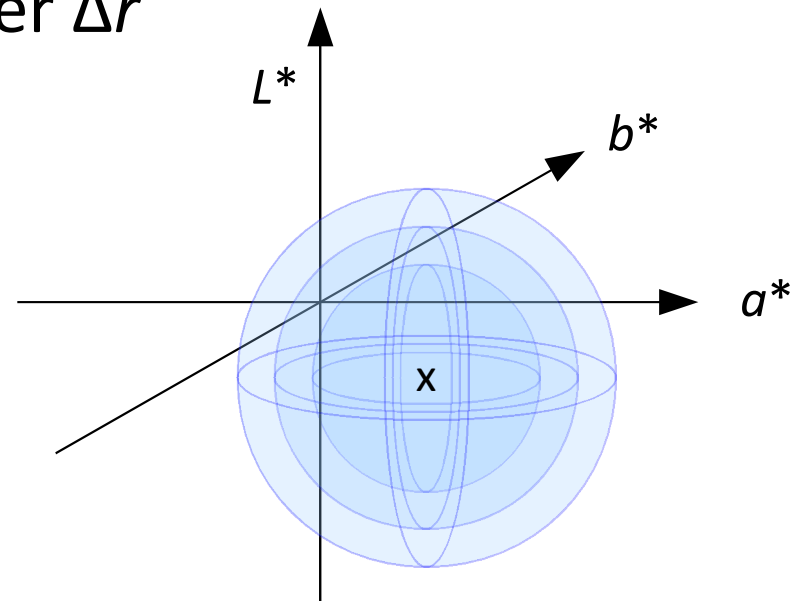
Constraint

- ## Difference (c_d)

  - ### Distance between 2 colors assigned to 2 variables

    - Larger distance makes higher satisfaction degree

- ## Maintenance (c_m)

  - ### Distance between assigned color and the original color

    - Smaller distance makes higher satisfaction degree

Mapping color difference to satisfaction degree [0, 1]
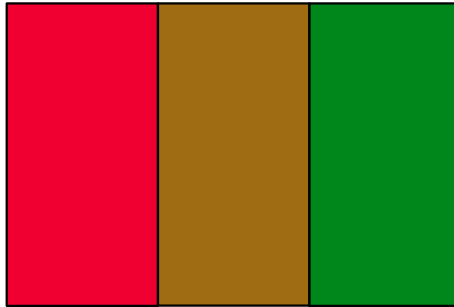
Fuzzy relations

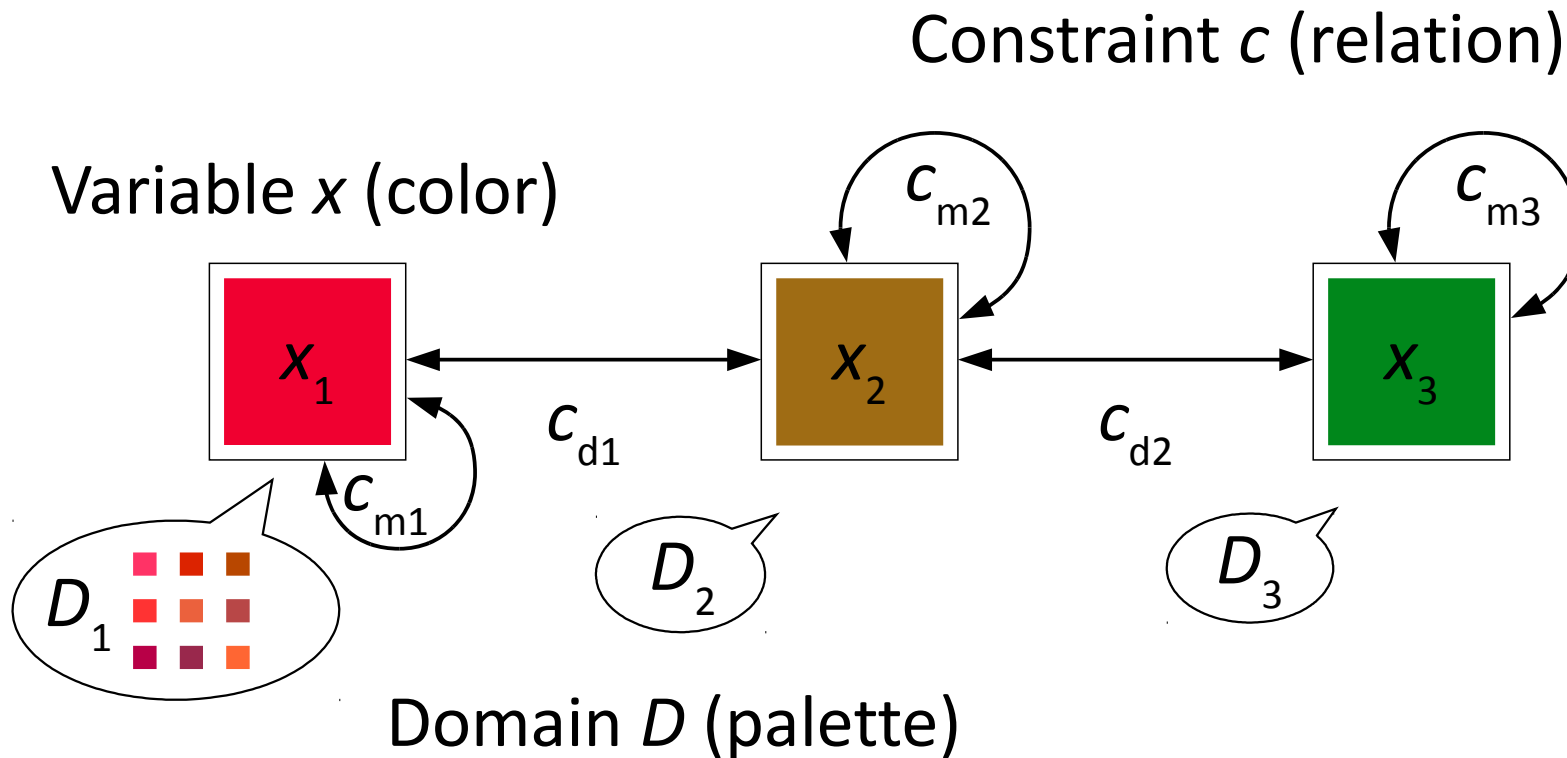A larger distance makes a higher satisfaction degree.
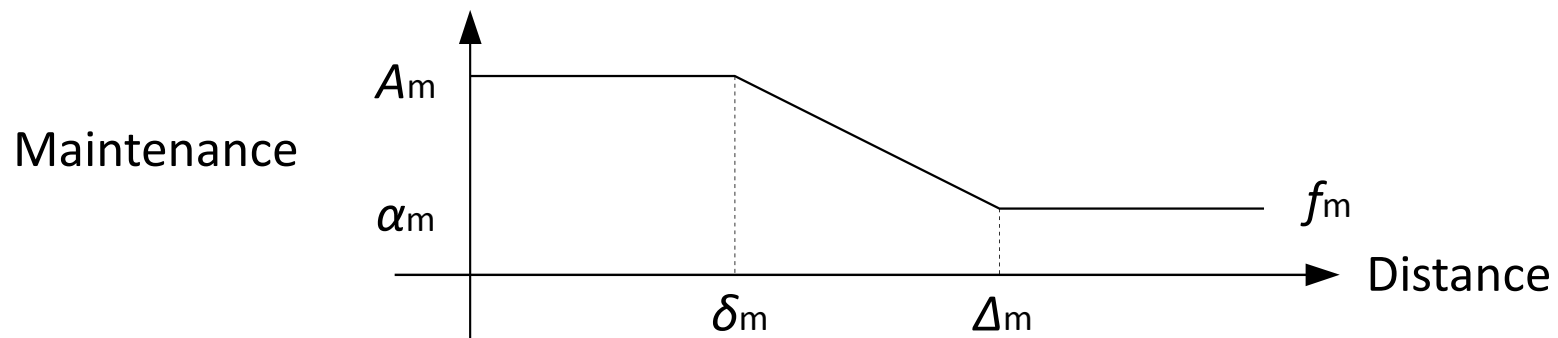
A smaller distance makes a higher satisfaction degree.

Example

To improve the 3-tone color scheme

Representation as FCSP

Formulated color scheme problems

- Color scheme problem

  - Variables (colors)

  - Domain (palette)   →   Solver   →   Solution
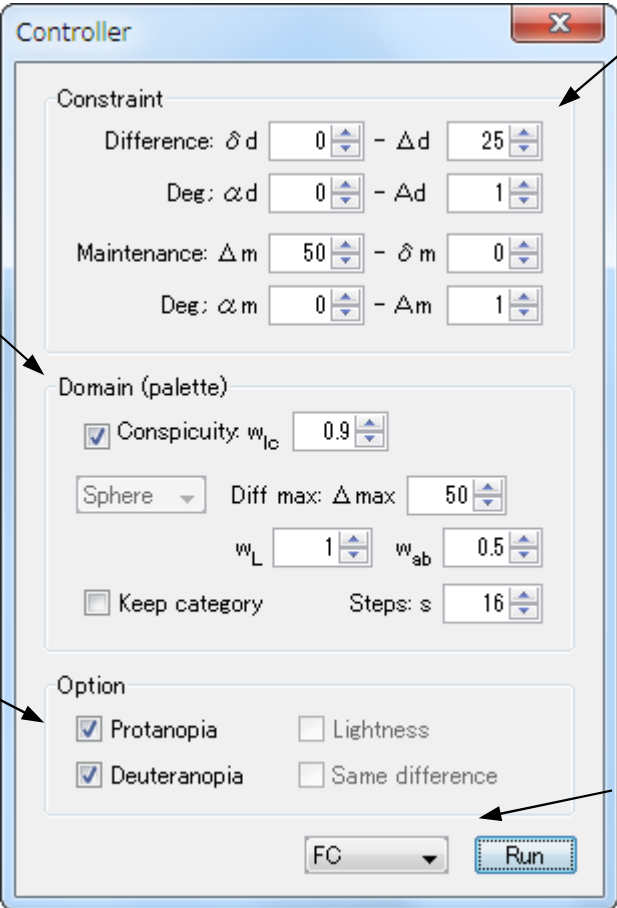
  - Constraints

Implementation (View window)

Conspicuity and difference from the original

Switch of color vision

Color differences in each color vision

Implementation (Controller window)

Relation between satisfaction degrees and color differences

Conspicuity setting
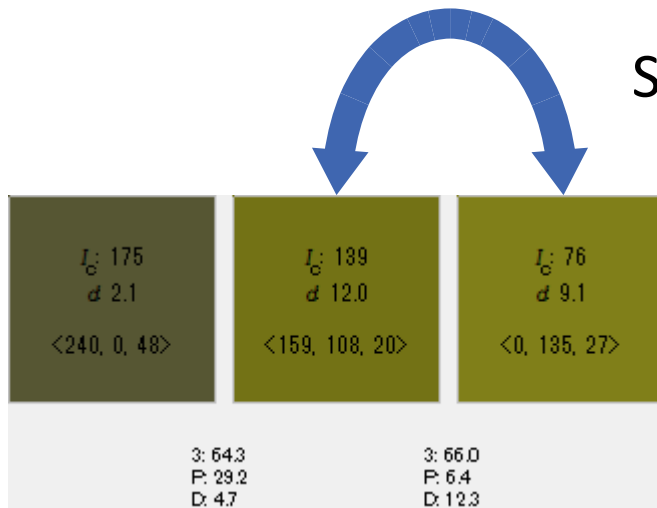
Color vision setting

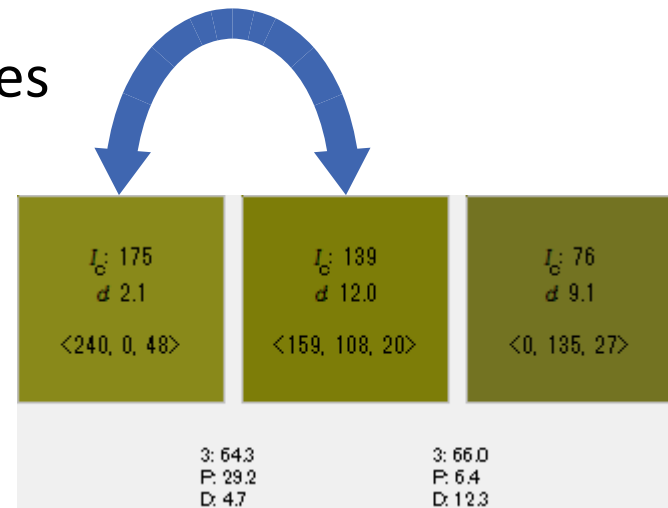Selection of solvers

Example of behavior (1)

Before
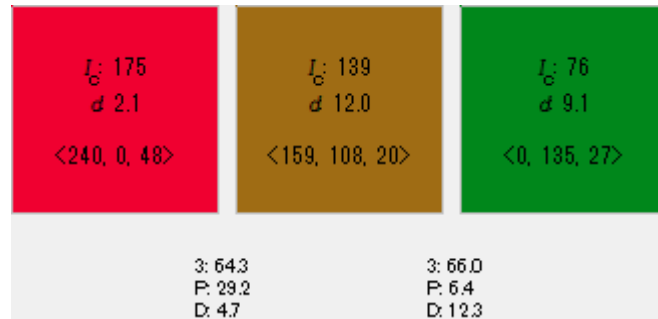
Type 3

Small differences

Type P

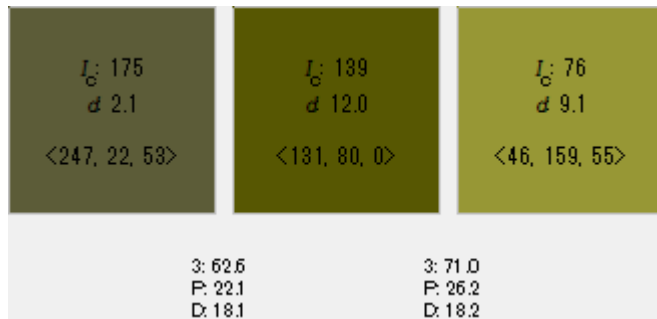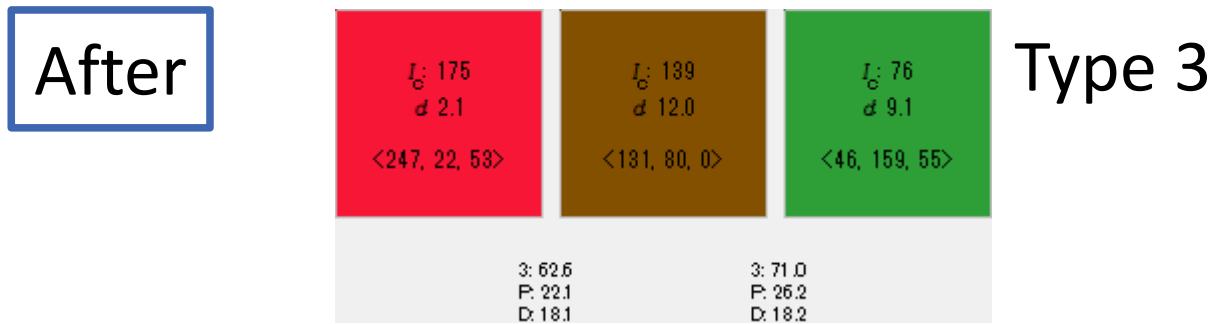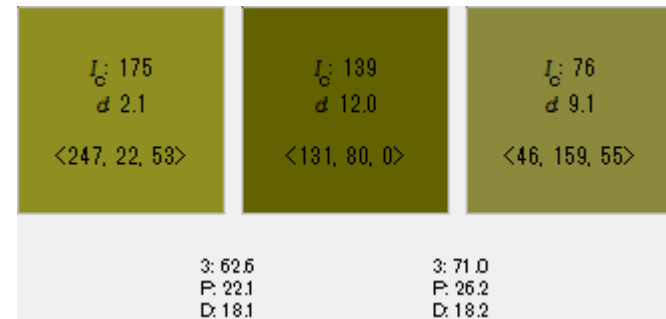Type D

Example of behavior (2)

After Type 3

Type P   Type D

Discussion

- Can I actually get a solution?

  - Yes. By suppressing palette sizes, a solution is derived in a few seconds.

- Is the solution appropriate?

  - Yes, because the method is based on knowledges of psychophysics.

  - However, we need to perform experiments with subjects

Conclusion

- Formulation of color scheme problem as fuzzy constraint satisfaction problem (FCSP)

  - To enlarge differences of colors in different color visions

  - To maintain the original color scheme as possible

- Developing a prototype tool for adjustment of color scheme

For 'color universal design' and 'art design'

Future work

- To apply various knowledge of psychophysics

  - Newer simulation of color visions

  - Visual perception of elderly people

  - Categorical perception of colors

- To Implement a tool and evaluate it

Fusion of the fields of psychophysics and artificial intelligence

Automatic Color Scheme Adjustment for Different Color Vision

Website:
`http://www.nvrc.rie.shizuoka.ac.jp/takty/`

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