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Adapting palettes to Color Vision Deficencies by Genetic Algorithms

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Generative User Interface Design

- It offers new opportunities for experiencing creativity in engineering problems, by including meta-heuristics in the research into the solution space and producing new and unexpected artifacts

In contrast to traditional design ⟶ ***Role of the designer is to explore a solution space in order that a direct relationship between designers' intentions and artifacts***

⇩

Generative design involves the use of assisting techniques and systems for refining and completing the design task

Designers' Role

- The designer is no longer responsible for meeting a set of recommendations, guidelines and requirements in order to evolve the original idea
- The designers responsible for shaping the constraints on the dynamic process and its behavior
- The human designer free to drive the designing process, keeping him/her focused on creative thought

- Meta-heuristics used in Generative Design include
  - Self-organization
  - Evolutionary Techniques (GA, GP)
  - Interactive Evolution
  - Swarm Systems
  - Ant Colonies
  - Generative Grammars

- *Generative UI design is a new and innovative approach*
- It has been investigated only recently relatively to some aspects

  - Quiroz et al. encodes user interfaces as individuals in an Interactive Genetic Algorithms (IGAs), and run through a number of generations to help explore the space of UI designs.
  - Ichikawa et al. describe re-working of Web page color for Color-Deficient Viewers

Benefits of the generative approach

- A larger number of alternative can be explored thus pro-actively supporting human creativity and decision-making
- Different quality attributes and guidelines can be considered one at a time thus facilitating the trade-off between conflicting criteria
- Designers are free to focus on more value-adding tasks, leaving algorithms to fine-tune their choices
- Interfaces can be automatically adapted to a larger set of devices, and a more specific set of user preferences

➔ Application of Generative Design in the choosing colors in User Interface

Adapting Palettes to
Color Vision Deficiencies (CVDs)
by Genetic Algorithms

Context

- According to UK Disability Rights Commission: "*Color accessibility is the second most recurrent accessibility barrier to the Web for disabled users*"
- Color blindness, or Color Vision Deficiency (CVD), such as protanopes and deuteranopes is known to be a signicant barrier to effective computer use
- The importance of colors in an attractive and usable GUI
  - Attention management
  - Meaning of the colors

Aim

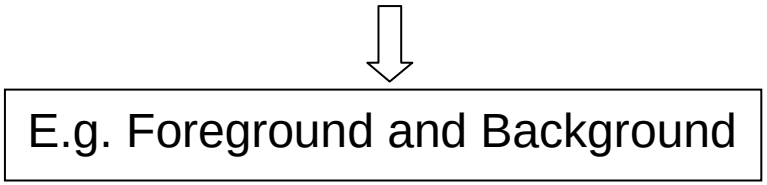
- Design of a Genetic Algorithm able to improve color usage in an interface in order to satisfy
  - Contrast requirements +
  - Chromatic choices of designers

Real-world applications

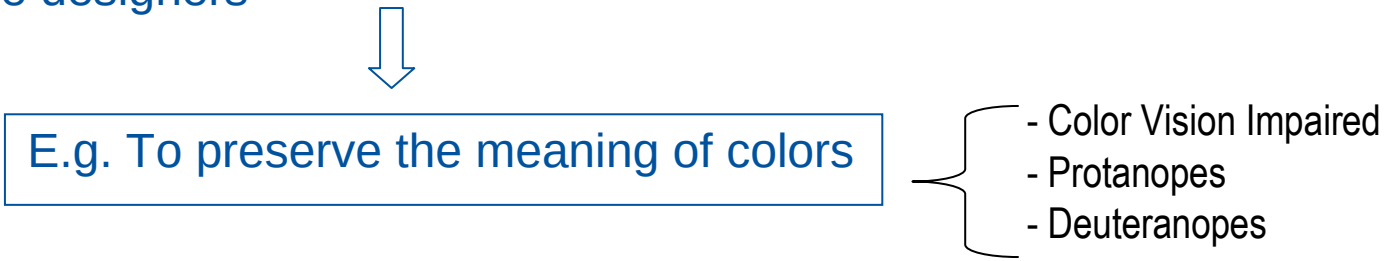
- Traditional desktop applications and Web applications:
  - Design of accessible interface for CVD users and improve color usage

Requirements

- The problem of finding the right palette for the User Interface is a common problem for a designer
- Requirements:
  - Luminance contrast among correlated colors to improve legibility



  - Preservation of chromatic choices and requirements as planned by interface designers

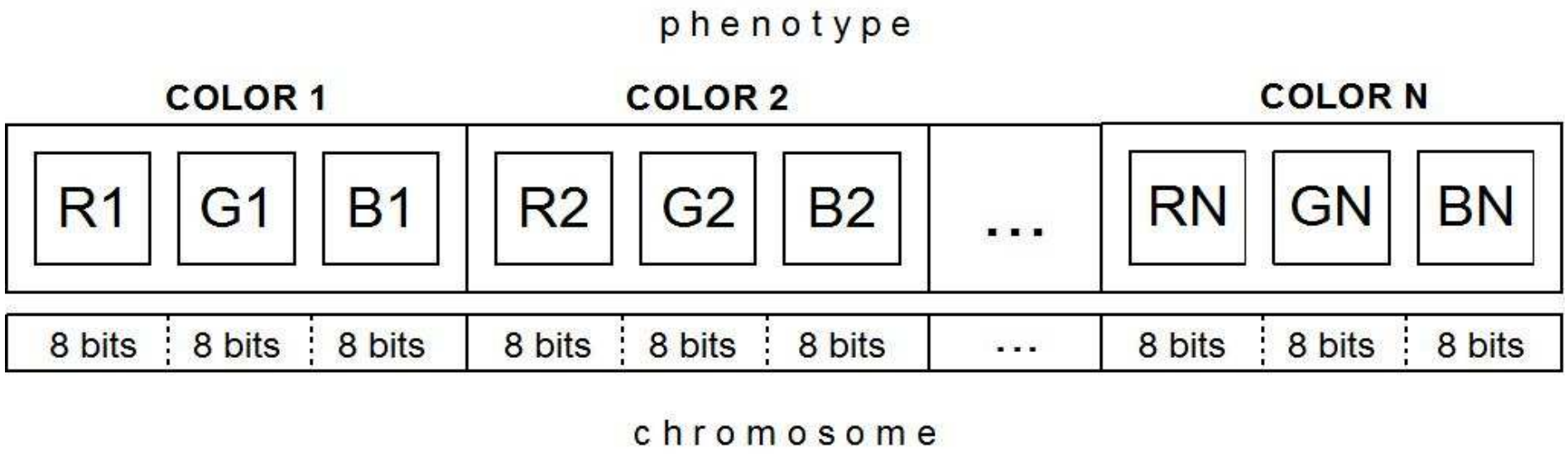


  - Guarantee color accessibility to a broader audience

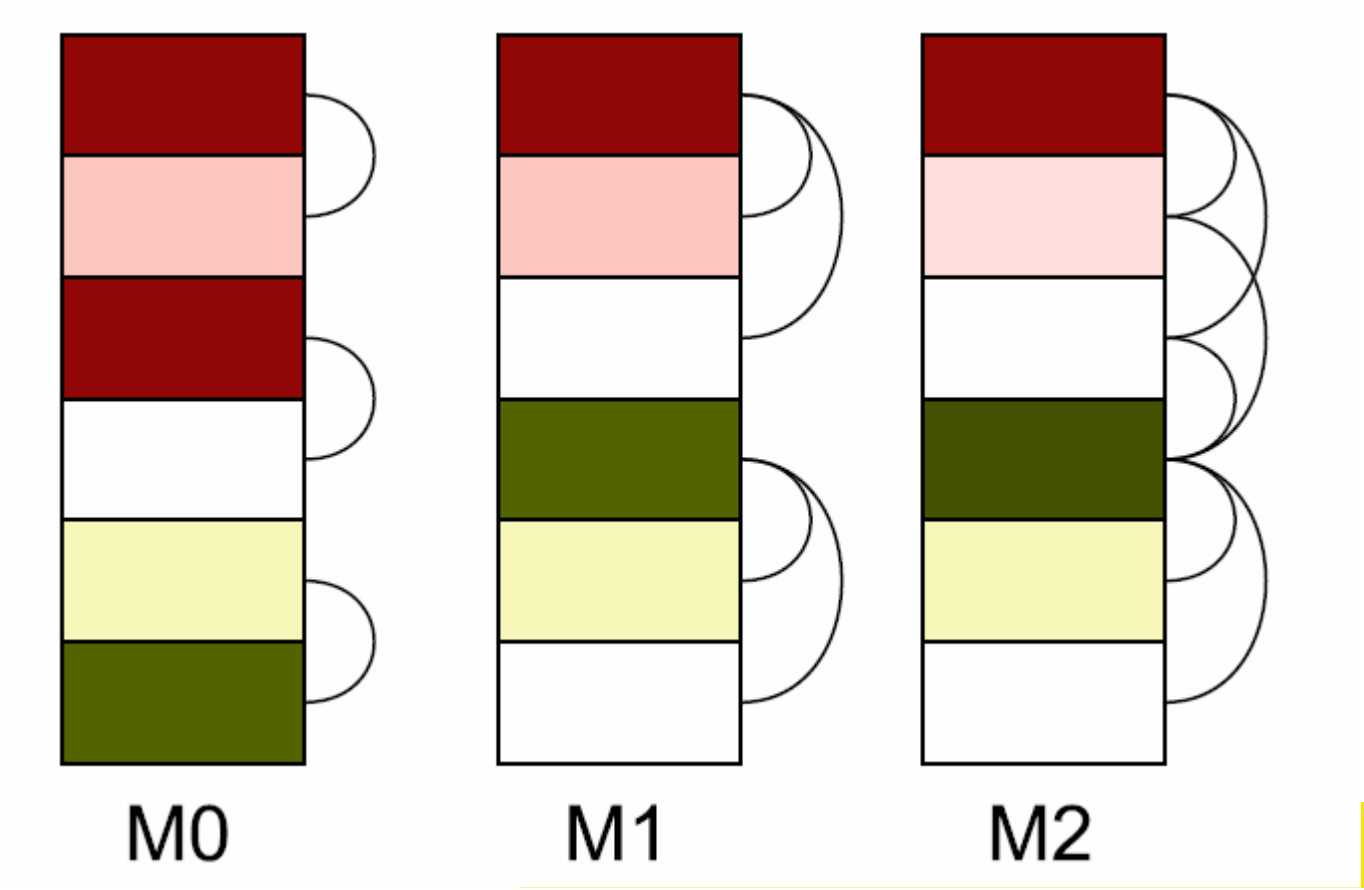
- These aspects are often conflicting criteria and make choosing the adopted palette a combinatorial optimization problem

Chromosome Structure

- Each gene represents a color which appears in User Interface
- Each color is composed by three component according to RGB color model (1 color coded in 24 bits)
- The phenotype is the set of colors in the interface (palette)

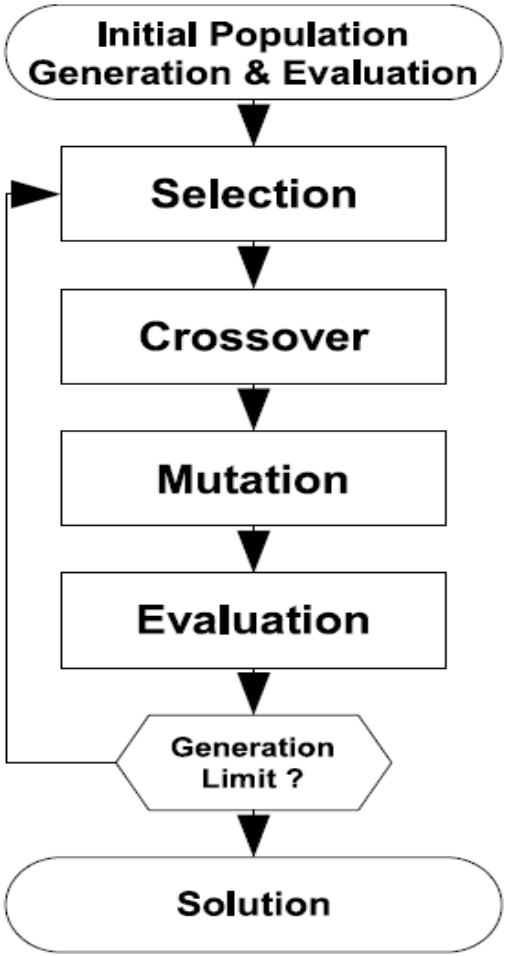


- Color Relationship
  - *Simple Model* (**M0**) → each pair of colors is put in the relationship of contiguity
  - *Intermediate Model* (**M1**) → triples of colors are made contiguous
  - *Complex Model* (**M2**) → multiple degree of correlation among colors



➔ Algorithm: Simple GA

1. Tournament Selection
2. Single Point Crossover
3. Bit switch Mutation



The algorithm was tested against two palettes

- Palettes made of 6 colors (132 bits)

⇩

Number of colors commonly used in an interface

- Palettes made of 16 colors (372 bits)

⇩

To study robustness of the algorithm when the number of colors increases

➔ Contrast

According to W3C WCAG 2.0 to reach level AAA of accessibility:

" *Text (and images of text) must have a **contrast ratio** of at least 7:1, except if the text is pure decoration. Larger-scale text or images of text can have a contrast ratio of 5:1* "

Contrast Ratio ⇨ $$C = \frac{\max(L_1, L_2) + 0.05}{\min(L_1, L_2) + 0.05}$$

where L_i is the ***Relative luminance*** of color ***i***

Definition:
Relative luminance = Relative perceived brightness of any point, normalized to 0 for black and 1 for maximum white

➔ **Fitness**

$$f = \left(\prod_{i=1}^{n} (1 - d_i) \prod_{j=1}^{k} c_j \right)^{\frac{1}{n+k}}$$

Distance of resulting color *i* from the original one

$$d_i = \frac{\Delta E_i}{\Delta E^*}$$

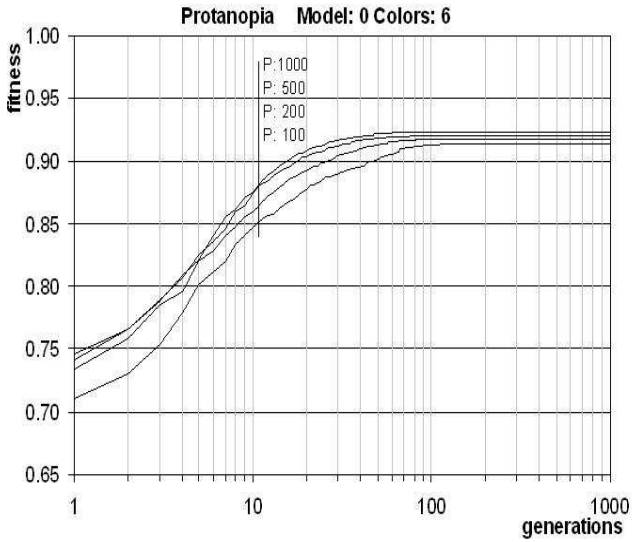
$$\Delta E = \sqrt{(L*_1 - L*_2)^2 + (a*_1 - a*_2)^2 + (b*_1 - b*_2)^2}$$

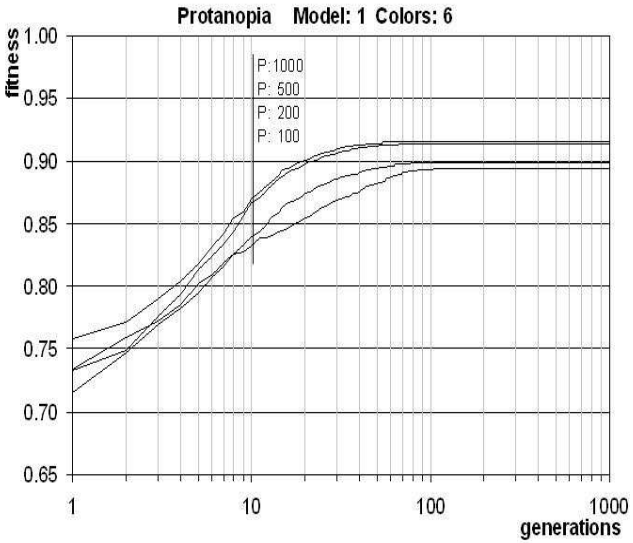
Contrast ratio of the *k* pairs of contiguous colors

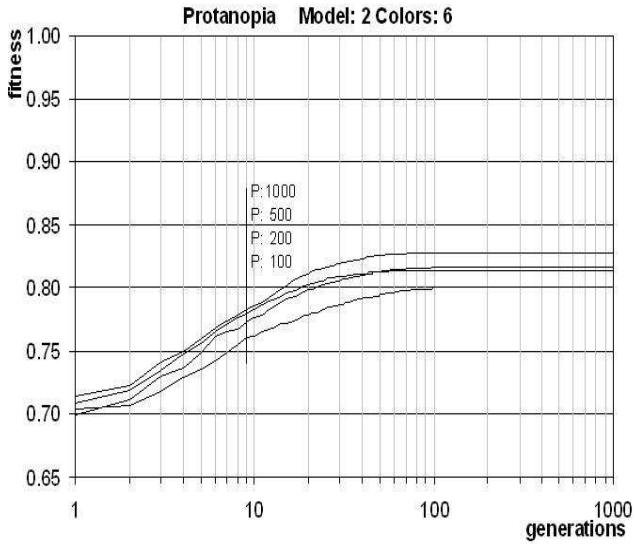
$$c_j = \frac{20 + \min(C_j - T_j, 0)}{20}$$

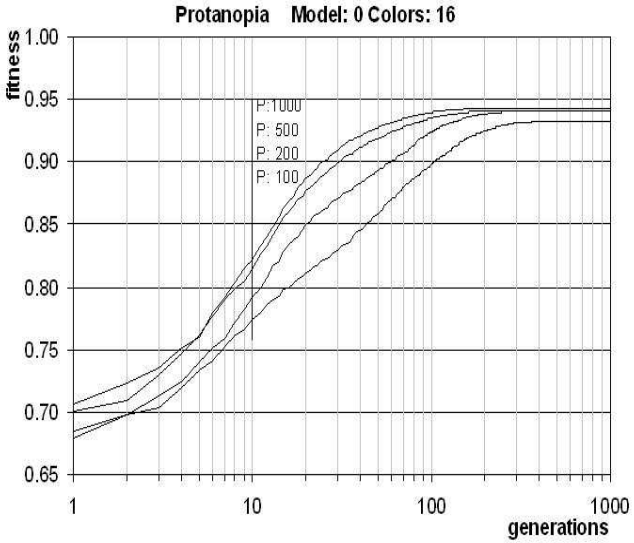
Experimental Results

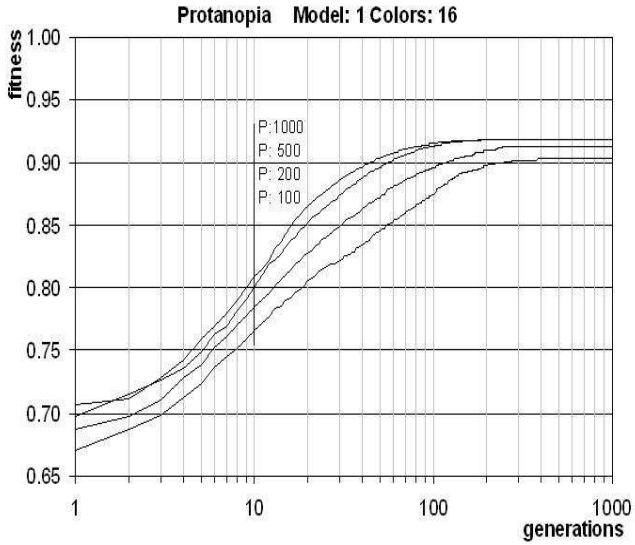
- 10 runs for different problem configurations
- The average behavior of the algorithm

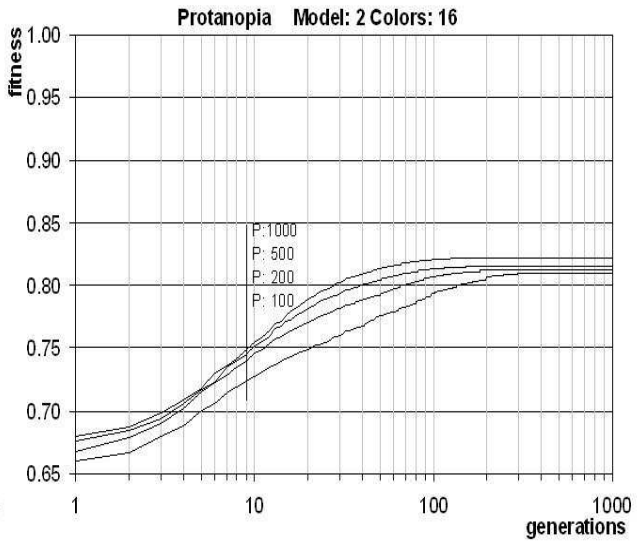


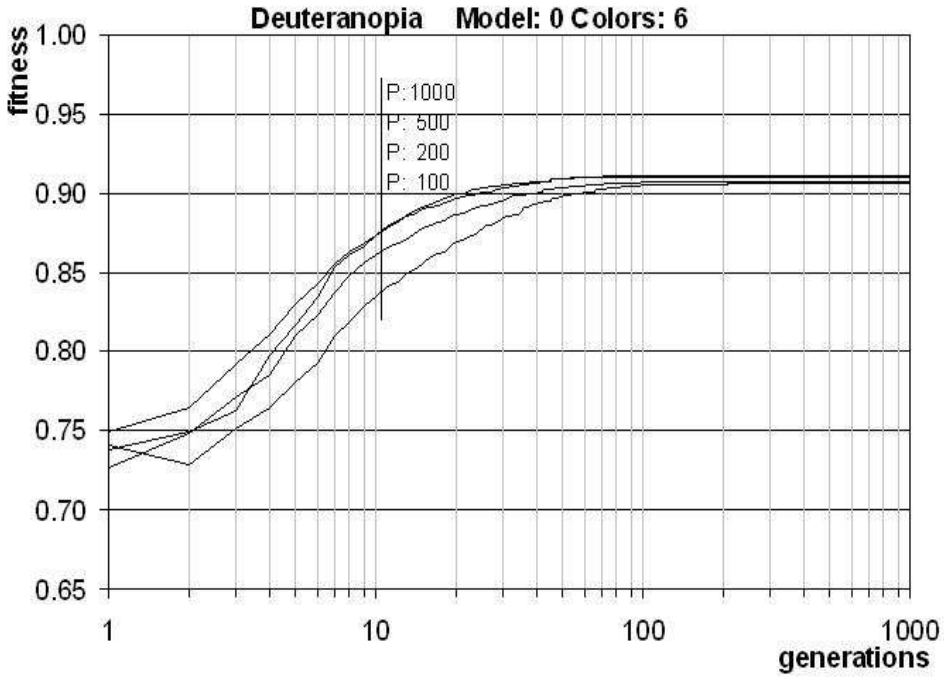











Deuteranopia Model: 0 Colors: 6
fitness
1.00
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P:1000
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P: 200
P: 100
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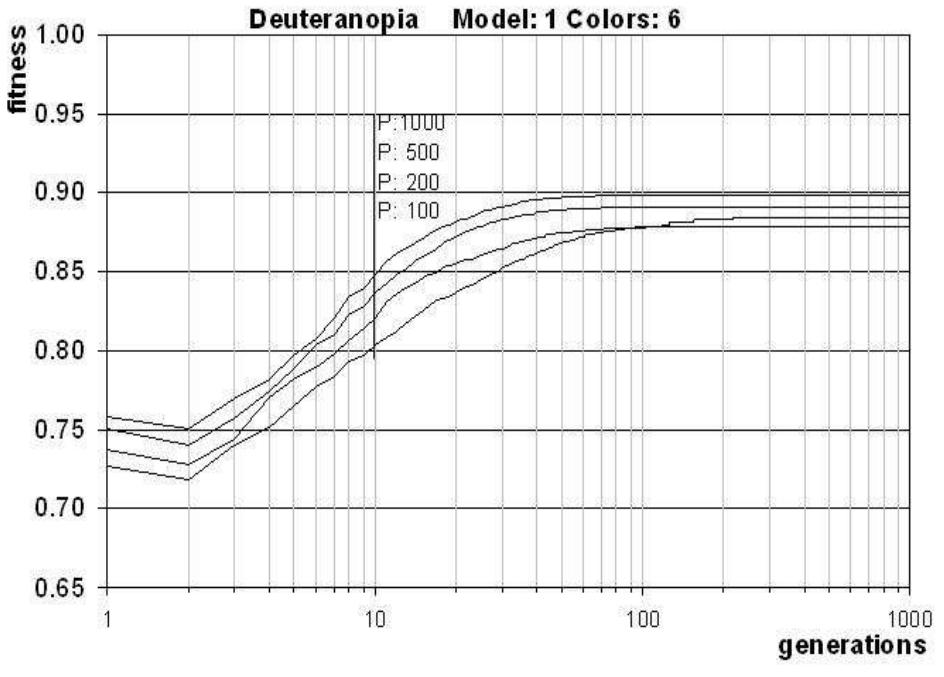
generations


Deuteranopia Model: 1 Colors: 6
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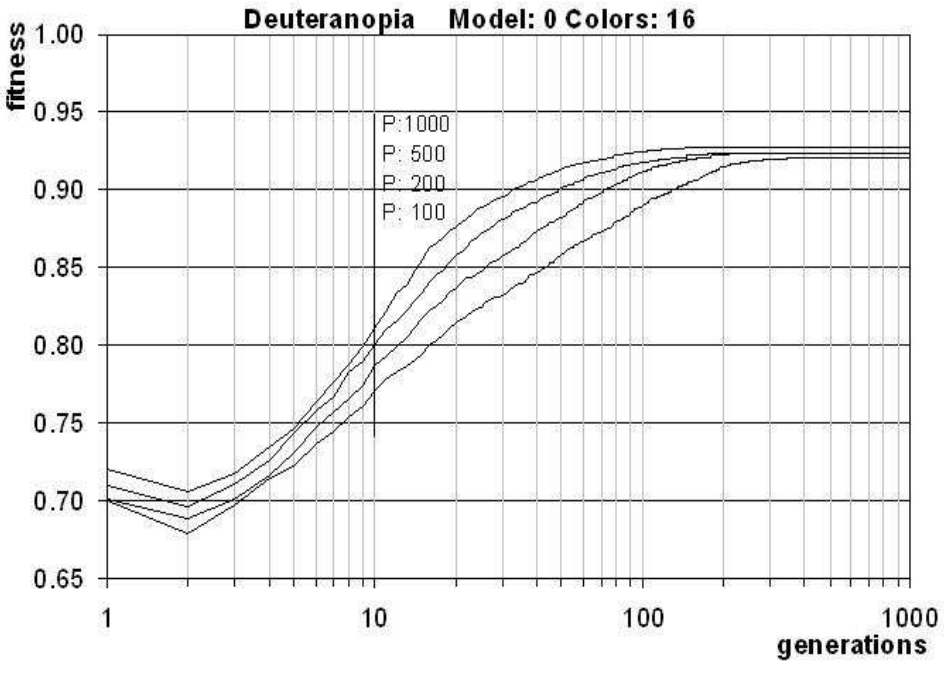
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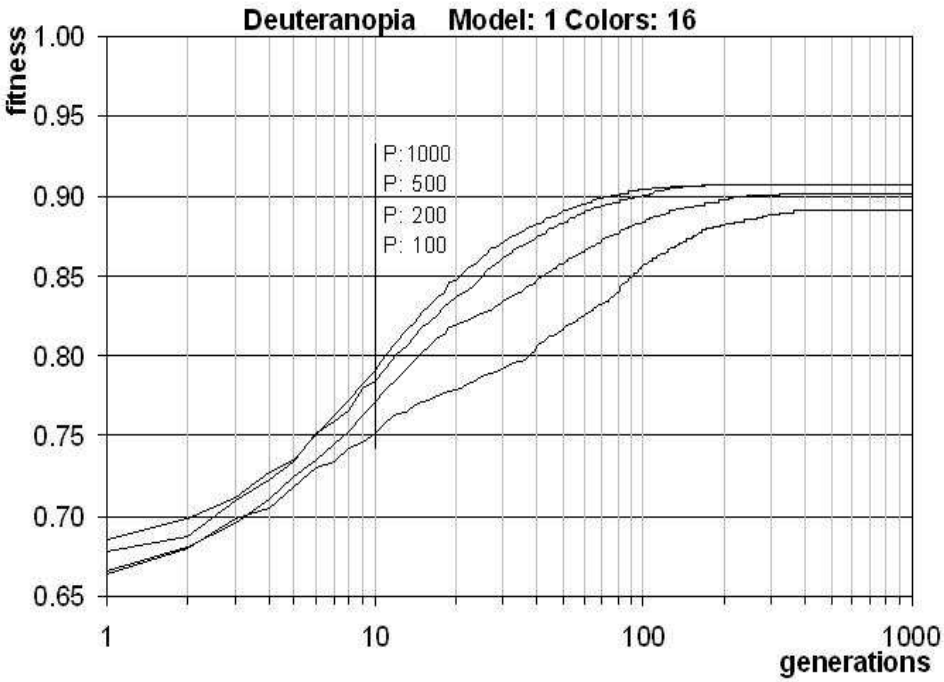
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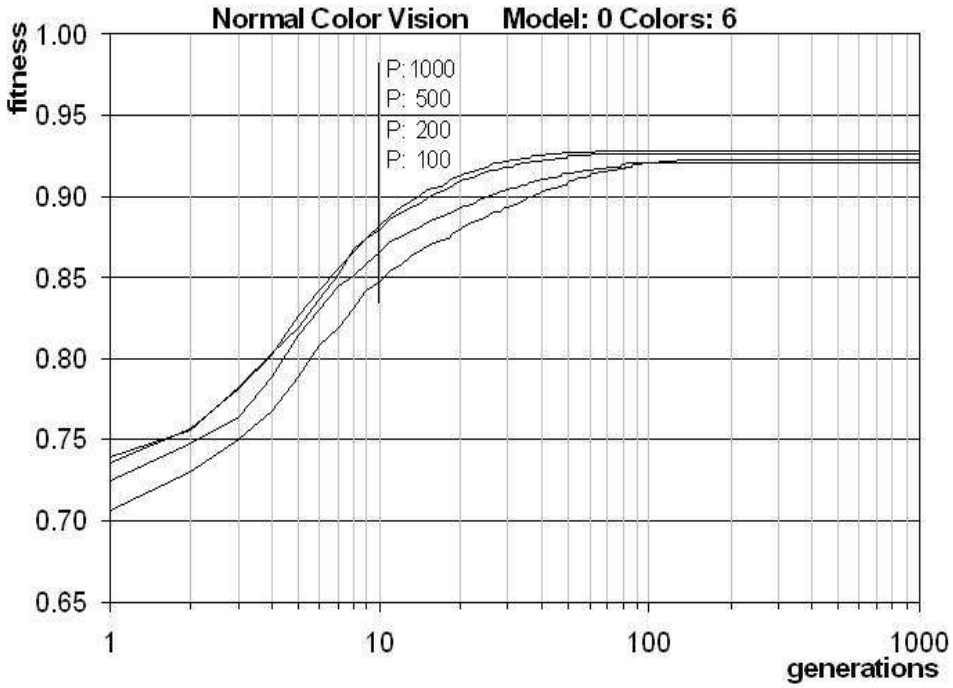
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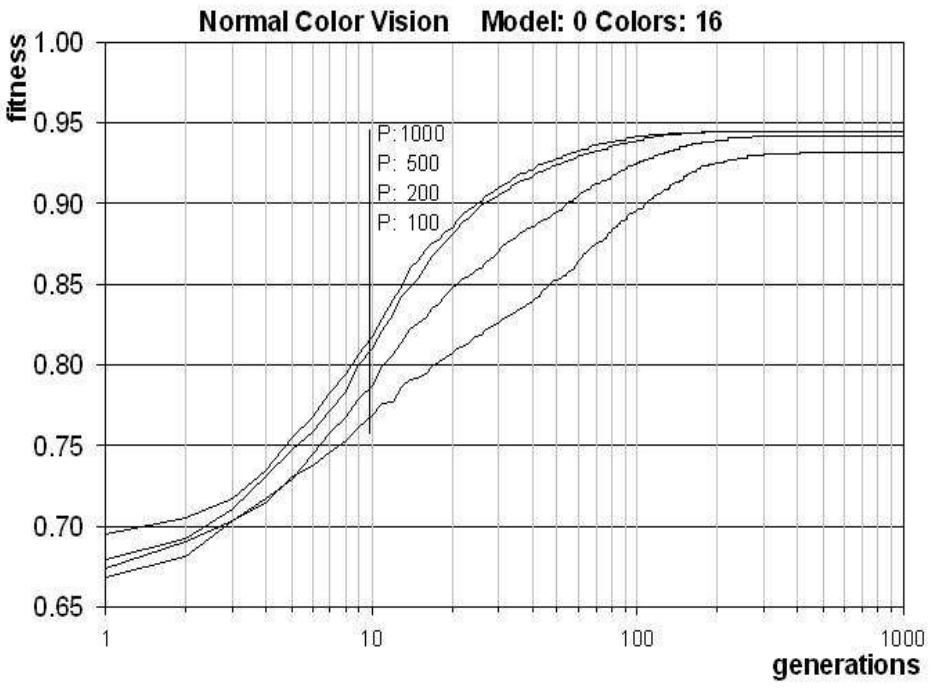
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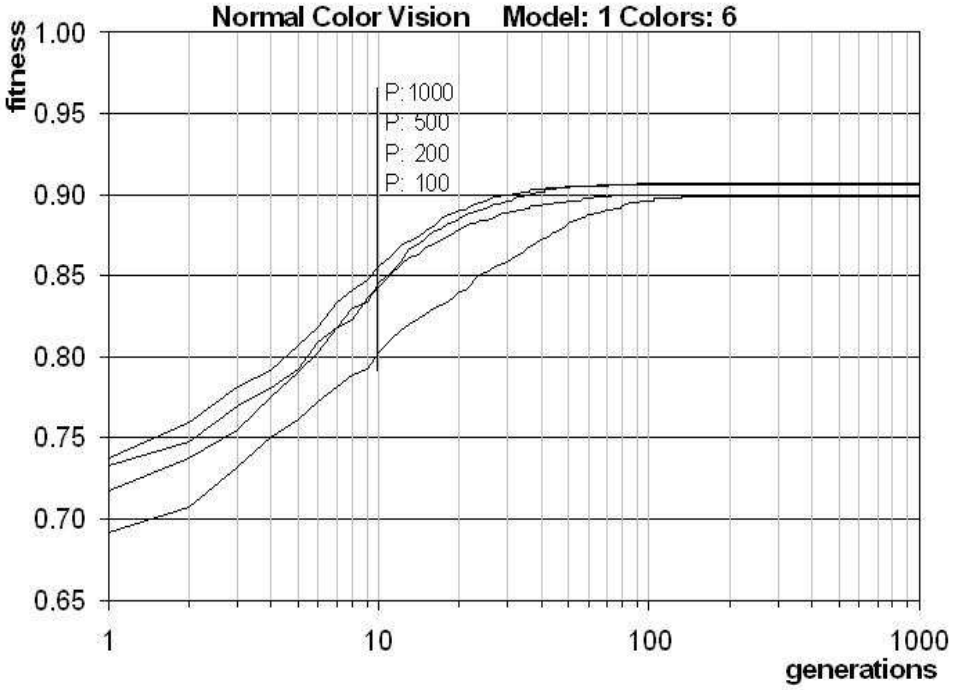
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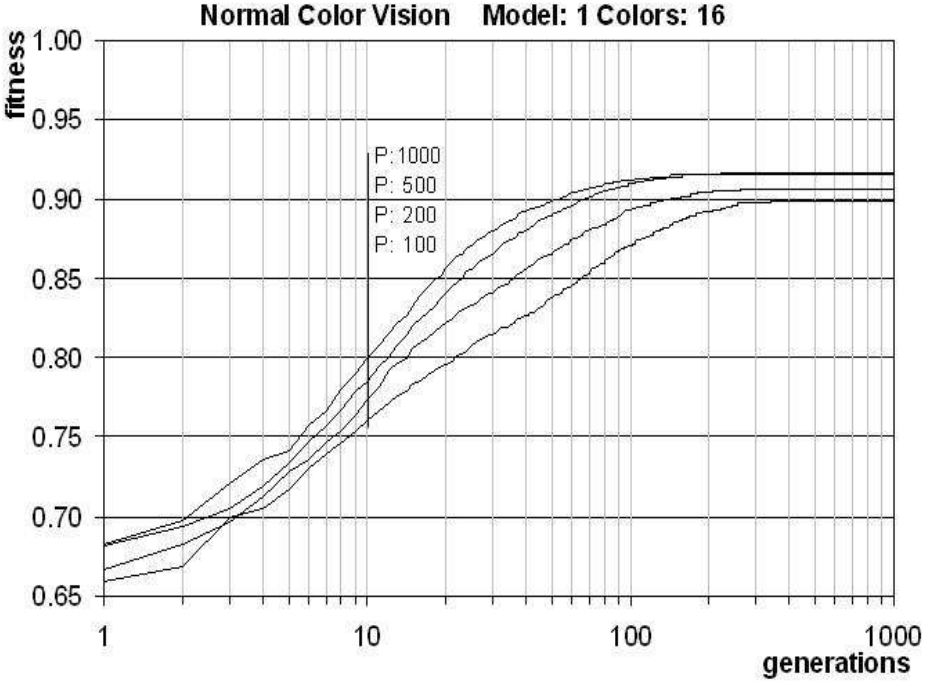
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P: 200
P: 100
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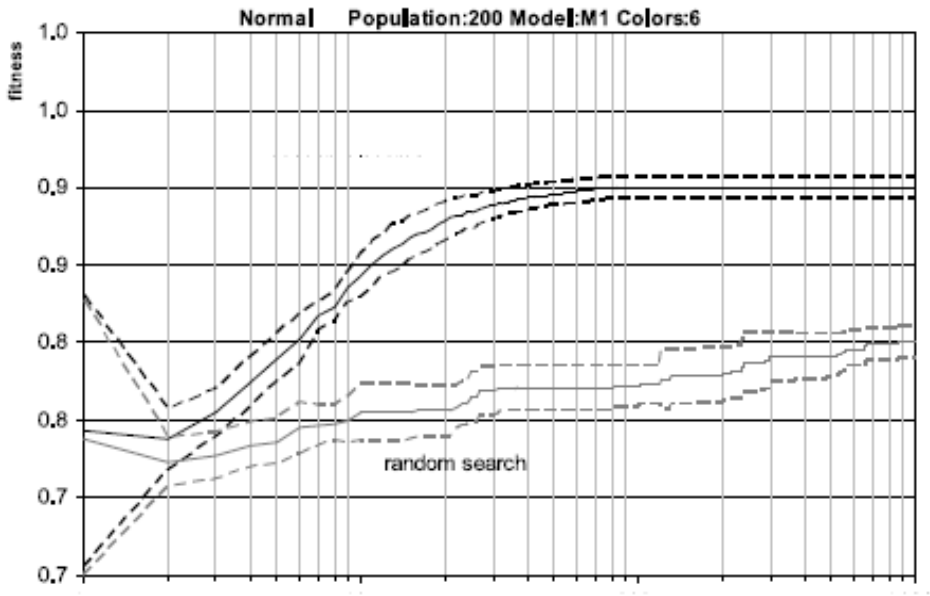
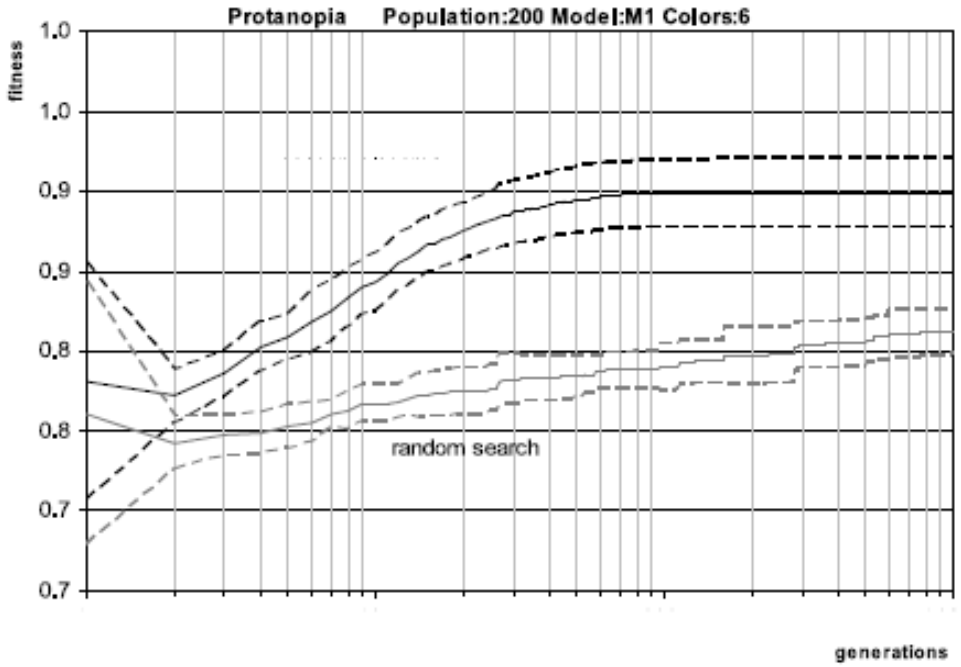
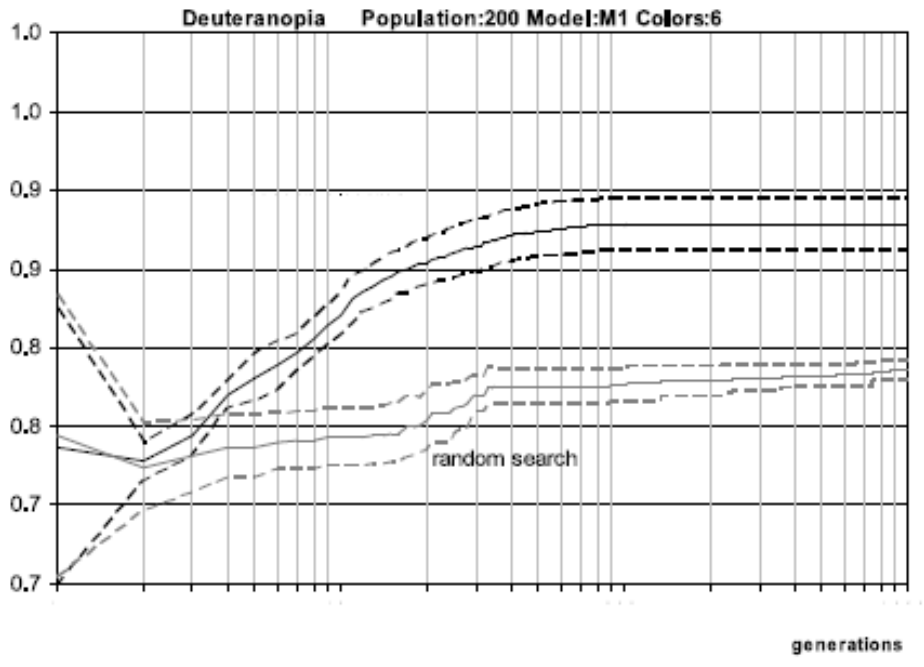
generations

Algorithm Performance:

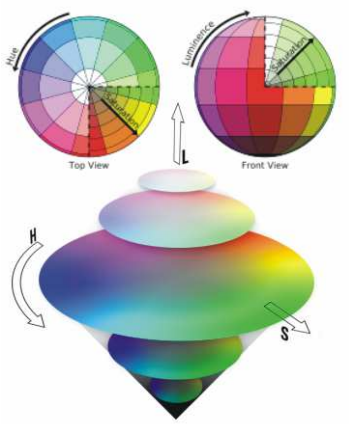
- ***Comparison with Radom Search for:***
  1. ***Normal Users***
  2. ***Protanopes***
  3. ***Deuteranopes***







Example of application

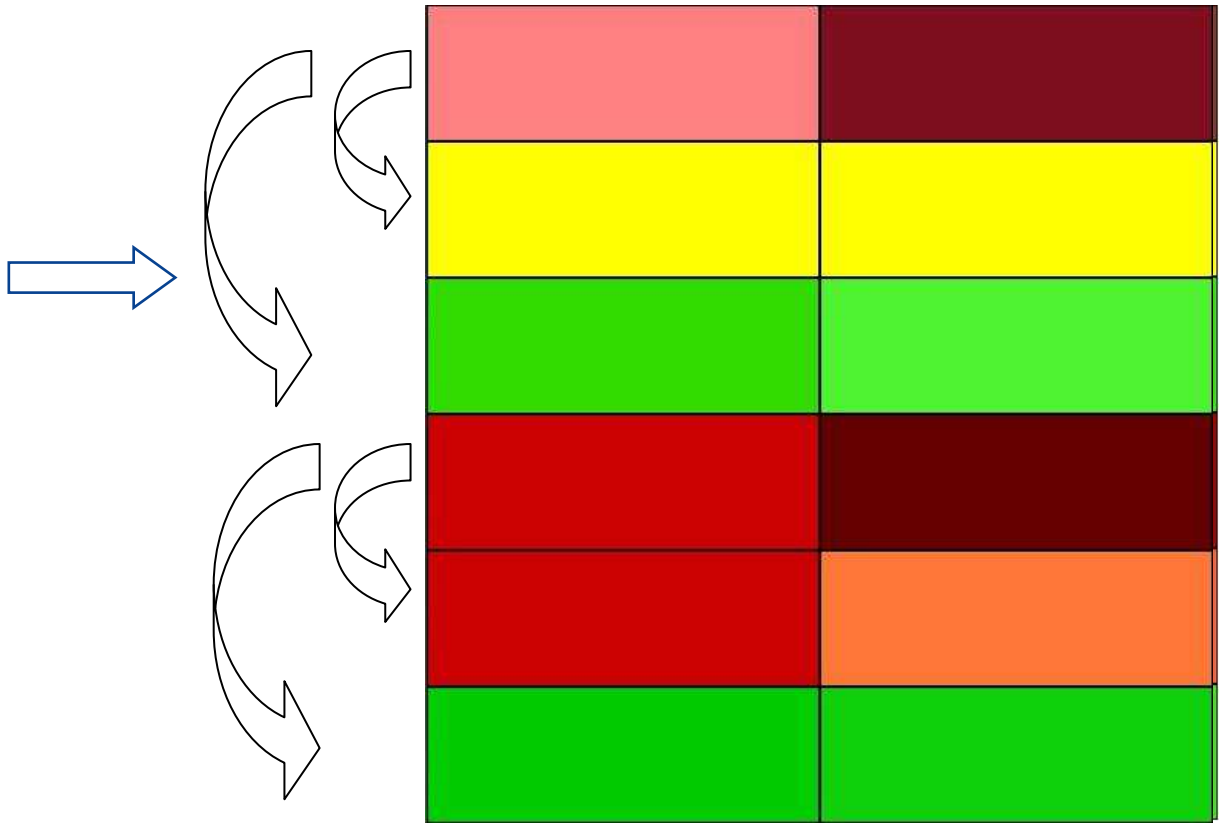


- Optimization of initial palette in order to
  1. Improvement of Luminance Contrast between related colors
  2. Preservation of the original chromatic settings

Input

- Initial palette defined by GUI Designer
- Color Vision Deficiency (protanope, deuteranope,..)
- Color relationship

Result



Conclusions

- We have designed a genetic algorithm for optimizing the colors in a GUI keeping into the account
  - ***Accessibility for Color Vision Deficiency Users***
  - ***Guidelines and Recommendation (W3C - WCAG 2.0)***
- We use a GA as a viable approach to optimization of contrast between colors in a User Interface

Future Work

- Exploring other color vision deficiency and the color vision needs in users with glaucoma, macular degeneration and cataratte by experimentation with test-groups
- Finding out ***implicit preferences*** by analyzing the usage of generated web pages or finding out ***explicit preferences*** during designing phase (***Interactive evolutionary computation***, IGA)