SIMPLEST PALETTE CHOICE IN PHYSICAL FIELD COLOR VISUALIZATION

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Introduction

It’s necessary to present and analyze results after numerical calculations have been made. Built-in graphic facilities in the most program packages or special software are at hand. Modern Fortran compilers and software packages Intel (R) Array Visualizer, Surfer (R) Golden Software Inc. are examples. There is an opportunity to use the preset palette, and to create an own palette with the use of the primary colors RGB (R – red, G – green, B – blue).

It is known that using 4, 16 or 32 color palettes, a human eye can perceive every color border, but 256 colors allow to create a continuous palette from the point of view of a person having normal chromatic sensitivity [1]. The quantity of colors usually equals to 6 or more bits for each primary color. Half – tone palette of each of the primary colors, and their additive compounds can be applied. However, in small resource programmable controllers the application of long encodings is sometimes a hard problem.

The decision to use a man – made color palette was taken (this may be called both subjective color scale [1] and pseudo colors [2]), and should meet the following conditions:
1) the encoding of 6 bit for each primary color;
2) the quantity of colors is less than 256;
3) human eyes must perceive color transitions as if they were close to continuous ones;
4) a human being should identify both a maximum and a minimum of a temperature field reflection.

Experimental procedure

15 people with normal chromatic sensitivity have taken part in the experiment. A 14 – inch color monitor with cathode ray tube and 320/200 pixel resolution was used. There was no color scale relating to temperature, and the task for the people was to identify minimums and maximums with the naked eyes.

The experiments showed the following results:
1) pallets that meet conditions exist;
2) pallets that meet conditions are close to the metal tarnish colors when the metal is in the flame, and the lowest temperature is visually dark – blue, the highest temperature is light – yellow. Evidently, the human brain ability to use visual experience is realized;
3) pallets that do not satisfy the conditions contain the primary green half – tones. This type of palette is used for geologic – geophysical maps coloured from blue to brown and green hues.

Numerical result

As a result of experiments, one variant of the subjective palette was created. The palette consisted of 190 colors and was calculated by the following algorithm:

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Section 1

palette(i) = color(r(i), g(i), b(i)), \quad i = 0,1,\ldots,190

\begin{align*}
    r(i) &= \begin{cases} 
        63 & : \ i \in [0,110] \\
        174 - i & : \ i \in [111,174], \\
        0 & : \ i \in [175,190] 
    \end{cases} \\
    g(i) &= \begin{cases} 
        63 & : \ i \in [0,46] \\
        110 - i & : \ i \in [47,110], \\
        0 & : \ i \in [111,190] 
    \end{cases} \\
    b(i) &= \begin{cases} 
        47 - i & : \ i \in [0,46] \\
        0 & : \ i \in [47,78] \\
        i - 79 & : \ i \in [79,110], \\
        32 & : \ i \in [111,174] \\
        207 - i & : \ i \in [175,190] 
    \end{cases}
\end{align*}

where \(r(i), g(i), b(i)\) – functions of red, green and blue colors; \(i\) – color index; \(color(r,g,b)\) – function of additive color mixing. Fig. 1. shows the suggested palette colors.

Then images of calculated physical fields on the basis of two test problems due to the suggested palette were made. Finite – difference methods on the quadrangular grid were applied. So, for filling up data inside the mesh by the use of bilinear interpolation the following equation was made:

\[ f(x, y) = a + bx + cy + dxy, \]

where \(a, b, c, d\) are coefficients calculated for each elementary mesh according to the grid nodes.

Test problem 1

Consider the gas flow in the axisymmetric Laval nozzle. At the inlet nozzle \(M < 1\), at the nozzle exit \(M > 1\). It is assumed that the gas is ideal and the flow is steady and is described by the equations:
\[
\frac{\partial y\rho u}{\partial x} + \frac{\partial y\rho v}{\partial y} = 0, \quad \frac{\partial y(p + \rho u^2)}{\partial x} + \frac{\partial y\rho uv}{\partial y} = 0,
\]

where \(x\) and \(y\) are the longitudinal and transverse coordinates, \(u\) and \(v\) are the projections of the velocity onto the \(x\) and \(y\) axes, \(\rho\) is the density, \(P\) is the pressure, \(H = \frac{p\gamma}{\rho(\gamma - 1)} + \frac{u^2 + v^2}{2}\) is the total enthalpy, \(\gamma\) is the adiabatic index of the gas.

Evidently, the type of the above mentioned equations changes from elliptic to hyperbolic in the transition from subsonic to supersonic flows. For this reason, the approximate factorization method in the subsonic flows and near the sonic line was applied [3], MacCormack scheme was used in the supersonic flows [4]. Fig. 2 shows the application of the suggested palette and Mach number distribution at the grid nodes and the filled-up image.

![Mach number distribution in the nozzle: (a) at grid nodes, (b) filled-up image.](image)

**Test problem 2**

Calculation visualization results of the transient temperature field on one of the panels of the device section of the spacecraft are shown in the following pictures. The spacecraft position relatively to the Sun, device operation cyclogram and the heat pipe effect were considered. Problem statement was described in [4], numerical data on temperature fields were kindly placed at our disposal by A.S. Tkachenko. Temperature distribution at the time moments related to the temperature minimum, intermediate values, temperature maximum are presented in the accompanying figures 2, 3, 4. As indicated in the picture with the identification mark “a”, initial data at differential grid nodes are cited. The picture with the identification mark “b” presents the filled-up initial data results.

**Conclusion**

The palette of 190 colors for each primary RGB was designed by using 6 bit encoding. On the basis of the suggested palette visualization of physical fields in the thermal and gas dynamic problems was made. Color distribution was smooth. The scale is not necessary for visual identification of minimum and maximum.
Section I

Fig. 3. Temperature distribution on the panel with temperature minimum: 
(a) at grid nodes, (b) filled-up image.

Fig. 4. Temperature distribution on the panel with intermediate temperature value: 
(a) at grid nodes, (b) filled-up image.

Fig. 5. Temperature distribution on the panel with temperature maximum: 
(a) at grid nodes, (b) filled-up image.

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