

Palette knife a simple tool to enrich color in physics simulations graphs



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Abstract

We describe a simple but useful computer program developed in order to improve the appearance of graphs where temporal or spatial descriptions are required. Palette mapped graphs are elaborated under C language using *winbgim.h* graph library; its objective is to emulate the *graphics.h* graph library. This library is part of the commercial compiler Borland C++ and facilitates the mouse functions. With the above mentioned library is possible to create graphs applications with GNU compilers such as the environment DevC++ in the same way that these graphs are created in the commercial Borland C++. The palette knife was designed using the RGB description; it makes reference to the color composition in terms of the intensity of primary colors. With this simple software tool we have the feasibility to obtain vivid and less stepped color graphs. We are including three physical simulations as an example of its use: the heat transfer of a metallic rod, the magnetic field produced by the Helmholtz coil and the rainbow phenomenon. The preparation of didactic material by the teacher with the student's participation in the development of tools like the one here presented can help to maintain the interest of the students on the physics courses inside and outside the classroom and also represents the opportunity of increasing the student computer skills.

Keywords: Mapped graphs, graphs libraries, color scales.

Resumen

Describimos un programa de computadora simple pero útil que se hizo para mejorar la apariencia de gráficas donde son necesarias descripciones temporales o espaciales. Las gráficas mapeadas con la espátula se laboran en lenguaje C usando la librería de gráficos *winbgim.h*; esta tiene como objetivo emular la biblioteca *graphics.h*. Esta biblioteca es parte del compilador C++ de Borland que facilita las funciones del ratón. Con la biblioteca antes mencionada es posible crear aplicaciones gráficas con compiladores GNU tales como en el ambiente DevC++ de la misma manera que estos gráficos son creados en el lenguaje comercial C++ de Borland. La espátula se diseñó usando la descripción RGB, esta hace referencia a la composición de los colores en términos de la intensidad de los colores primarios. Con tal herramienta programática tenemos la facilidad de obtener gráficas de colores más vivos y menos escalonados. A manera de ejemplo de esta espátula incluimos tres simulaciones físicas: la transferencia de calor de una barra metálica, el campo magnético producido por una bobina de Helmholtz y el fenómeno del arcoíris. La preparación de material didáctico hecho por el profesor y con la participación de los estudiantes en el desarrollo de programas como el que se presenta aquí, ayudan a mantener el interés de los estudiantes por los cursos de física dentro y fuera del aula y también representa la oportunidad de incrementar las habilidades computacionales de los estudiantes.

Palabras clave: Mapeo de gráficos, bibliotecas de gráficos, escalas de colores.

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I. INTRODUCTION

The data arise from experimental or a theoretical problem requires analysis in order to establish quantitative expressions that can be represented by means of graphs. The way the data is presented visually has a powerful effect on the perception and interpretation of the structure in those data. The plots enable viewers to identify patterns in

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confident values while preventing them from making inaccurate inferences based on uncertain values. In addition to simple line plots, you can fairly easily create more sophisticated graphs including color-mapped images with contouring and labeling with certain packages such as Mathematica, Matlab, LabVIEW and Python but you can't define custom color maps. The appropriate use of color is an area of particular interest. This is partly because the

perceptual impact of a color cannot be reliably predicted from knowledge of the red, green, and blue components generally made available to users [1]. A color scale is a pictorial representation of numerical values with each value assigned its own color. Since many of the colors in a scale might not be perceived as distinct, to achieve an informative representation it is important to maximize the number of distinct perceived colors along the scale, last referred to as the number of barely noticeable differences. The scales that preserve the order of magnitude of the primaries r , g , and b appear to induce a natural order. However there are more complex methods to build color scales, i.e. the optimal scale that maximizes the number of just noticeable differences. In order to do that it is necessary to consider that the viewer is sensitive to changes in lightness. A sense of order results from color scales that start with a dark color for the smallest value and end with a light color for the largest value, going through colors with increasing lightness. The lightness $l(c)$ of a color $c=(r, g, b)$ is determined by the measure of its distance from black. The hue and the saturation are considered [2, 3].

II. THE PALETTE KNIFE

To create palette-mapped (MP) graphs we wrote a program in C language employing the graph library, *wingim.h* [4]. This library has the objective to emulate the library *graphics.h* of the commercial compiler Borland C++ and expedite some functions of mouse. With the above mentioned library we can create the graphs applications with GNU compilers such as the Dev C++ environment. In the same way, they can be created with the Borland C++ compiler. The palette knife was designed using the *rgb* description, it make reference to the color composition in function of primary colors intensities. In order to indicate the proportion of color mixed in each shade that to make the color scale; we particularly assigned one value to each primary color, i.e. the 0 value means in our case that the color does not participate into the mixing, while increasing the value means that it has more contribution to intensity, even though the values interval could any. In example the real numbers between 0 and 1, or real numbers between 0 and 37, etc. It is frequent for each primary color to codify as one byte (8 bites). Then usually the intensity of each of the components was measured according to one scale that embraces from 0 to 255 numbers. In this manner the black is determined by (0, 0, 0) while the white color is expressed like (255, 255, 255). In Fig. 1, we show the applied distribution in the screen for the tracing of the function, together with the location of the label and the palette of colors. The function *putpixel* (*int x*, *int y*, *COLOR* (*int R*, *int G*, *int B*)) assigns (in the position (*x*, *y*) of the graphic window) one specific color to each pixel. It is the base of the program as we show in Fig. 2.

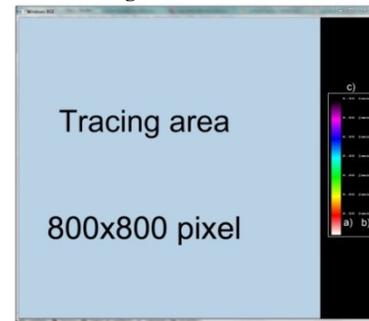


FIGURE 1. Tracing area of 800x800 pixel. Where: a) Assigned value, b) Units, and c) Color label.

```
//Bm,Bmx,minimum and maximum values;B,expected value;u,unit.
void keypk(int x,int y,double Bm,double Bmx,char const *u)
{ double b,c; int n,a,a1,x1,y1; char key[10];
  b=(Bmx-Bm)/6;//calculates the value for each interval.
  for (n=0;n<=6;n++)
  { c=Bm+n*b;
    x1=x+30;
    sprintf(key,"%0.2f %s",c,unit);
    y1=y+n*50;
    outtextxy(x1,y1,key);
  }
//Write to the position (x, y) the value assigned.}
//Start the stroke color palette
for (a=0;a<=255;a++)
{ for (a1=0;a1<=255;a1++)
  { x1=x+a1;
    putpixel(x1,y+a*50/255,COLOR(a,0,a));
    putpixel(x1,2*y+(a*50/255),COLOR(255-a,0,255));
    putpixel(x1,3*y+(a*50/255),COLOR(0,a,255));
    putpixel(x1,4*y+(a*50/255),COLOR(0,255,255-a));
    putpixel(x1,5*y+(a*50/255),COLOR(a,255,0));
    putpixel(x1,6*y+(a*50/255),COLOR(255,255-a,0));
    putpixel(x1,7*y+(a*50/255),COLOR(255,a,a));
  }
}
}

void gradient(int x, int y, double B, double Bm, double Bmx)
{ int b; double c;
  //Calculate the numerical value
  c=6*(B-Bm)/(Bmx-Bm);
  //(between 0-6) for color assignment.
  if (c<=1)
  { b=int(c*255);
    putpixel(x,y,COLOR(b,0,b));
    //black-magenta}
  else
  { if (c<=2)
    { b=int((c-1)*255);
      putpixel(x,y,COLOR(255-b,0,255));
      //magenta-blue}
    else
    { if (c<=3)
      { b=int((c-2)*255);
        putpixel(x,y,COLOR(0,b,255));
        //cyan-blue}
      else
      { if (c<=4)
        { b=int((c-3)*255);
          putpixel(x,y,COLOR(0,255,255-b));
          //cyan-green}
        else
        { if (c<=5)
          { b=int((c-4)*255);
            putpixel(x,y,COLOR(b,255,0));
            //green-yellow}
          else
          { if (c<=6)
            { b=int((c-5)*255);
              putpixel(x,y,COLOR(255,255-b,0));
              //yellow-red}
            else
            { if (c<=7)
              { b=int((c-6)*255);
                putpixel(x,y,COLOR(255,b,b));
                //red-white}
              else
                putpixel(x,y,WHITE);
            }
          }
        }
      }
    }
  }
//For values that pass the maximum value
//is assigned the color white.} } } }
```

FIGURE 2. Source code. The two main functions of the program are showed. The function *keypk* draws the color palette with the label and the *gradient* function that makes the trace.

III. GETTING STARTED: THREE PHYSICAL EXAMPLES

In addition to simple line plots, it is possible to create more sophisticated graphs, including color-mapped images with the color palette. With the purpose of illustrating the use of the palette knife, we show three simulations on physics problems common to students of sciences and engineering. First, we consider the heat diffusion through solids [5], in this example the solid is homogeneous and has transverse section constant area. The color palette offers several advantages; one of them is that we can appreciate the temperature change along the solid. This feature is very intuitive and allows the opportunity to see a different scheme for other platforms. We consider a metallic rod of length l connected in its extremes to a pair of heat sources at temperatures T_i and T_f respectively (see Fig. 3). To any time and position the function of temperature is $T(x, t)$ with a differential equation that describes the thermal conduction given by

$$\alpha \frac{\partial^2 T(x, t)}{\partial x^2} = \frac{\partial T(x, t)}{\partial t}, \quad (1)$$

where $\alpha = \frac{K}{\rho c}$, with K the thermal conductivity, ρ the density and c the calorific capacity. Then with the proper boundary conditions that describe this problem [6], we obtain the series of plots included in Fig. 4.



FIGURE 3. The heat transfer system.

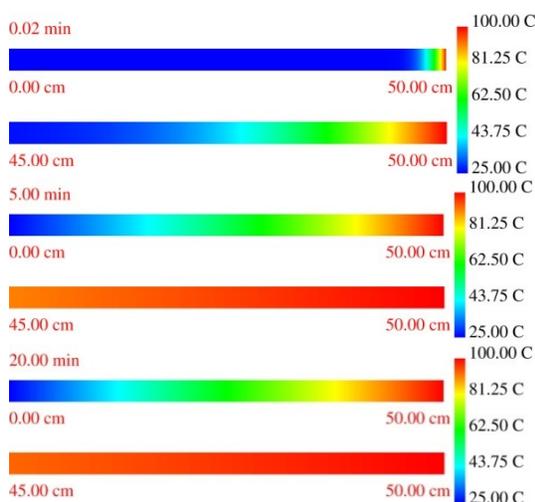


FIGURE 4. We consider a rod of silver of 50 cm of length and a diffusion coefficient of $1.73 \text{ cm}^2/\text{s}$. The initial temperature of the rod was 25°C , as for one of the extremes; the other extreme was kept at 100°C . We include the images from complete length and for 45 to 50 cm.

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The second simulation that we have considered is the Helmholtz coil problem. The term Helmholtz coils refers to the geometrical arrangement of two identical, parallel, circular, coaxial, current-carrying coils whose midplane separation is equal to their mean radius a . These coils are a common arrangement used to produce magnetic fields needed for many laboratory applications. The geometric symmetry of the coils produces a field of high uniformity near their center which is supposedly calculable from the coil radius and current. Calhoun [7] has examined the uniformity of the field in the midplane of the coils. Crosser *et al.* [8] developed a series expansion for the calculation of the magnetic field near the center of Helmholtz coils and applied the result to magnet design. Wang *et al.* [9] have examined the field uniformity for Helmholtz coils, whereas Good [10] introduced the elliptic integrals in order to recognize them before using any computational program to calculating, in particular, the magnetic field of Helmholtz pair of coils. In our case the purpose is to obtain a map of the inside and out of the space between coils. We have two coils with N turns with a separation distance d . By first applying Biot-Savart to one coil of radius a (see Fig. 6) where a current flow I in direction dl , we can obtain the magnetic field as:

$$B = \frac{\mu_0 i}{4\pi} \oint \frac{dl \times r}{r^3}, \quad (2)$$

we also observe that $dl = d\theta$ then it is possible to obtain $dl \times r$ and by symmetry the magnetic field will be confined to the xz plane and changing x for ρ and y for $\hat{\theta}$ and substituting in Eq. (2) and separating the field components we can obtain B_ρ, B_θ, B_z . Both B_ρ, B_z are solved using elliptic integrals [10] and B_θ is zero. Then considering the two coils of N turns separated by distance d , with the coordinates origin displaced by $\pm \frac{d}{2}$ and applying the superposition principle for each components we have

$$B_{tot\rho} = \frac{N\mu_0 i}{2\pi\rho} \times, \quad (3)$$

$$\left[\left(\frac{z_1}{\sqrt{z_1^2 + (a + \rho)^2}} \right) \left(\frac{z_1^2 + a_1^2 + \rho^2}{z_1^2 + (a - \rho)^2} E_1 - K_1 \right) \right. \\ \left. + \left(\frac{z_1}{\sqrt{z_2^2 + (a + \rho)^2}} \right) \left(\frac{z_1^2 + a_1^2 + \rho^2}{z_1^2 + (a - \rho)^2} E_2 - K_2 \right) \right]$$

$$B_{totz} = \frac{N\mu_0 i}{2\pi} \times, \quad (4)$$

$$\left[\left(\frac{1}{\sqrt{z_1^2 + (a + \rho)^2}} \right) \left(\frac{a^2 + z_1^2 + \rho^2}{z_1^2 + (a - \rho)^2} E_1 + K_1 \right) \right. \\ \left. + \left(\frac{1}{\sqrt{z_2^2 + (a + \rho)^2}} \right) \left(\frac{z_2^2 + a_1^2 + \rho^2}{z_2^2 + (a - \rho)^2} E_2 - K_2 \right) \right]$$

where $z_1 = z - \frac{d}{2}$ and $z_2 = z + \frac{d}{2}$. Here K_j y E_j are elliptic integrals of first and second order respectively, with $j=1, 2$.

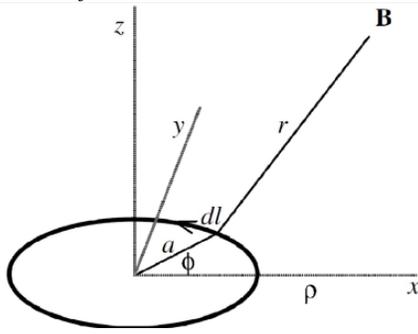


FIGURE 5. A circular loop carrying current i in the x - y plane.

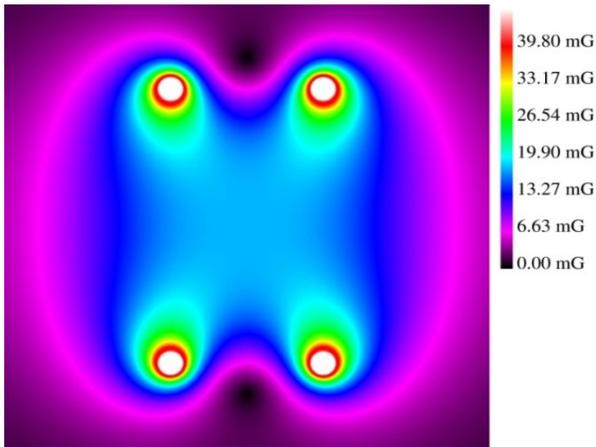


FIGURE 6. Simulation of Helmholtz magnetic field. We use 10 cm coil radius, 10 cm separation distance, 100 turns and 2 A of electrical current. Color scale: min. 0 mG and max. 39.80 mG.

We considered as third physics simulation the natural rainbow phenomena. The physical description of this phenomenon is often supposed to be a simple problem in geometrical optics, it is not true. The theory of rainbow was developed in the past decades. Rainbows can be characterized in terms of certain features: They appear when an observer looks towards the rain with the Sun behind it. Rainbows include a relatively bright band centered on a 42° angle above the direction of sunlight. The 42° angle remains the same as the observer moves toward or away from the rainbow [11]. The band itself is divided into colors with red, orange and yellow appearing at the top followed down through the spectrum to blue and violet at the bottom. Finally in the blue-violet region some rainbows exhibit dark bands. The spacings of light and dark in this region are the supernumerary bows, while the rainbow itself can be characterized as the primary bow. Attempts to explain the rainbow include prominent philosophers and scientists for example Aristotle, Roger Bacon, Theodoric of Freiburg, Descartes and Newton. Descartes and Newton, with only geometrical optics, explained the existence of primary and secondary bows and of the dark band that separates them [12, 13]. They calculated the dispersion of the scattered light into a spectrum. But their theory could

not explain the supernumerary arcs; the optical effect underlying supernumerary arcs was discovered in 1830 by Young. The pattern of supernumerary arcs is dependent of the radius of the droplet. In 1835 Richard Potter pointed out that the crossing of various sets of light rays in a droplet gives rise to caustic curves. Caustics and rainbows generally have a lighted side and a dark side. In order to determine the intensity distribution in the neighborhood of a caustic, in 1838 Airy was able to express the intensity of the scattered light in the rainbow region in terms of a new mathematical function, today called Airy function. There are other types of rainbows, the atomic and nuclear rainbows which have a wave mechanical treatment that was formulated in 1959 by Kenneth Ford and John A. Wheeler. The atomic rainbow was first observed in 1964 by E. Hundhausen and H. Pauli. It exhibits a primary rainbow and supernumerary peaks [14]. In 1975 Vijay Khare made a detailed comparison of three theories of the rainbow. Nowadays there are serious attempts to explain the high order rainbows. To the simulation we purposed a spherical drop with refraction index n surrounded by a media with refraction index m . With a reference system in rectangular coordinates centered in the point O that coincides with the drop center whose radius is r as we show in Fig. 7, and assuming that Sun rays are coming parallels to the axis OX, the minimum emerging angle of the drop can be calculated as [13]

$$\theta_j = j\pi + 2 \arcsin(\alpha_0) - 2(j + 1) \arcsin\left(\frac{m(\lambda)}{n(\lambda)} \alpha_0\right), \quad (5)$$

with $\alpha_0 = \sqrt{\frac{(j+1)^2 - (n(\lambda)/m(\lambda))^2}{(j+1)^2 - 1}}$ where j_0 is the order of rainbow. In Fig. 8 we show a simulation of a rainbow with air-water interface with refraction index of 1 and $1.32 + (3675.69/\lambda^2) - (67961154.98/\lambda^4)$.

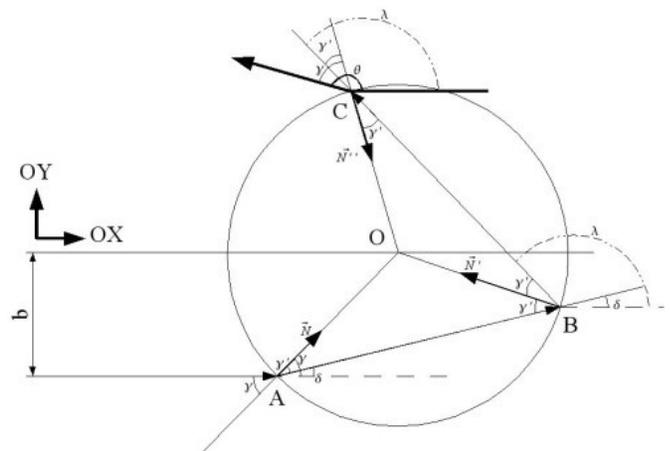


FIGURE 7. The first internal reflection generates the primary rainbow.

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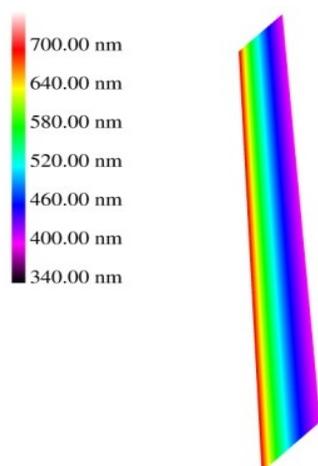


FIGURE 8. Rainbow simulation graph. Color scale: min. 340nm and max. 700nm.

IV. CONCLUSIONS

We have presented a simple program to improve the appearance of graphs where temporal or spatial descriptions are required. It is a typical demonstration on combined teacher-student effort in order to make the teaching-learning processes in and out of the classroom more motivating. The primary importance is student involvement with the simulations and their physics learning on the proposed problems. This experience suggests that other kinds of physical problems such as, mechanics, fluid flow, percolation, classical chaos and fractals, could have a large impact on education.

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