RGB to HSL conversion

Ask Question

I'm creating a Color Picker tool and for the HSL slider, I need to be able to convert RGB to HSL. When I searched SO for a way to do the conversion, I found this question HSL to RGB color conversion.

While it provides a function to do conversion from RGB to HSL, I see no explanation to what's really going on in the calculation. To understand it better, I've read the HSL and HSV on Wikipedia.

Later, I've rewritten the function from the "HSL to RGB color conversion" using the calculations from the "HSL and HSV" page.

I'm stuck at the calculation of hue if the R is the max value. See the calculation from the "HSL and HSV" page:

$$H' = \begin{cases} \text{undefined}, & \text{if } C = 0 \\ \frac{G-B}{C} \mod 6, & \text{if } M = R \\ \frac{B-R}{C} + 2, & \text{if } M = G \\ \frac{R-G}{C} + 4, & \text{if } M = B \end{cases}$$
$$H = 60^\circ \times H'$$

This is from another wiki page that's in Dutch:

$$H = \begin{cases} \left(0 + \frac{G-B}{MAX-MIN}\right) \times 60, & \text{als } R = MAX \\ \left(2 + \frac{B-R}{MAX-MIN}\right) \times 60, & \text{als } G = MAX \\ \left(4 + \frac{R-G}{MAX-MIN}\right) \times 60, & \text{als } B = MAX \end{cases}$$

and this is from the answers to "HSL to RGB color conversion":

```
case r: h = (g - b) / d + (g < b ? 6 : 0); break; // d = max-min = c
```

I've tested all three with a few RGB values and they seem to produce similar (if not exact) results. What I'm wondering is are they performing the same thing? Will get I different results for some specific RGB values? Which one should I be using?

```
hue = (g - b) / c;                  // dutch wiki
hue = ((g - b) / c) % 6;            // eng wiki
hue = (g - b) / c + (g < b ? 6 : 0); // SO answer


function rgb2hsl(r, g, b) {
    // see https://en.wikipedia.org/wiki/HSL_and_HSV#Formal_derivation
    // convert r,g,b [0,255] range to [0,1]
    r = r / 255,
    g = g / 255,
    b = b / 255;
    // get the min and max of r,g,b
    var max = Math.max(r, g, b);
    var min = Math.min(r, g, b);
    // lightness is the average of the largest and smallest color components
    var lum = (max + min) / 2;
    var hue;
    var sat;
    if (max == min) { // no saturation
        hue = 0;
        sat = 0;
    } else {
        var c = max - min; // chroma
        // saturation is simply the chroma scaled to fill
        // the interval [0, 1] for every combination of hue and lightness
        sat = c / (1 - Math.abs(2 * lum - 1));
        switch(max) {
            case r:
                // hue = (g - b) / c;
                // hue = ((g - b) / c) % 6;
                // hue = (g - b) / c + (g < b ? 6 : 0);
                break;
            case g:
                hue = (b - r) / c + 2;
                break;
            case b:
                hue = (r - g) / c + 4;
                break;
        }
    }
    hue = Math.round(hue * 60); // °
    sat = Math.round(sat * 100); // %
    lum = Math.round(lum * 100); // %
    return [hue, sat, lum];
}
```

colors converter rgb hsl

edited Feb 15 at 8:40

asked Aug 24 '16 at 8:45

akinuri
2,982 5 19 46

The English one looks correct to me, the Dutch one I don't recognise and I don't understand what it says on the wiki page. :) – Xotic750 Aug 24 '16 at 9:51

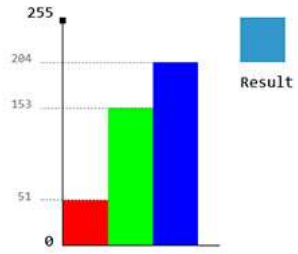
Here's the octave implementation of hsv2rgb: hg.savannah.gnu.org/hgweb/octave/file/549f8625a61b/scripts/… – knb Sep 18 '16 at 18:12

3 Answers

I've been reading several wiki pages and checking different calculations, and creating visualizations of RGB cube projection onto a hexagon. And I'd like to post my understanding of this conversion. Since I find this conversion (representations of color models using geometric shapes) interesting, I'll try to be as thorough as I can be. First, let's start with RGB.

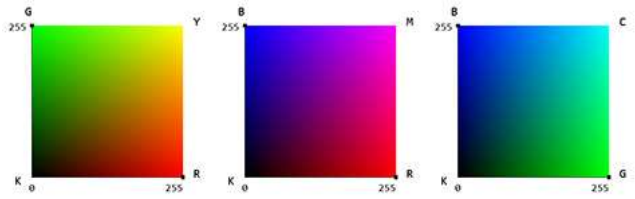
RGB

Well, this doesn't really need much explanation. In its simplest form, you have 3 values, R, G, and B in the range of [0,255]. For example, `51,153,204`. We can represent it using a bar graph:

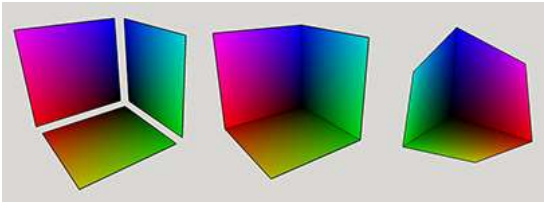


RGB Cube

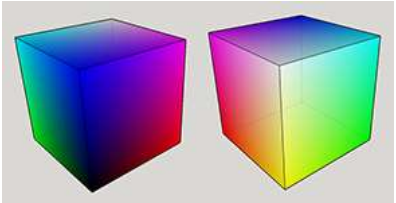
We can also represent a color in a 3D space. We have three values `R`, `G`, `B` that corresponds to `X`, `Y`, and `Z`. All three values are in the `[0,255]` range, which results in a cube. But before creating the RGB cube, let's work on 2D space first. Two combinations of R,G,B gives us: RG, RB, GB. If we were to graph these on a plane, we'd get the following:



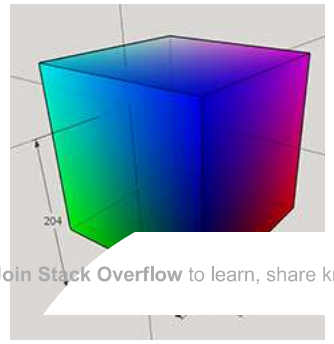
These are the first three sides of the RGB cube. If we place them on a 3D space, it results in a half cube:



If you check the above graph, by mixing two colors, we get a new color at (255,255), and these are Yellow, Magenta, and Cyan. Again, two combinations of these gives us: YM, YC, and MC. These are the missing sides of the cube. Once we add them, we get a complete cube:

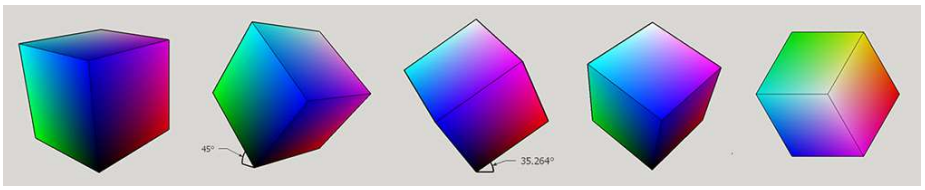


And the position of `51,153,204` in this cube:

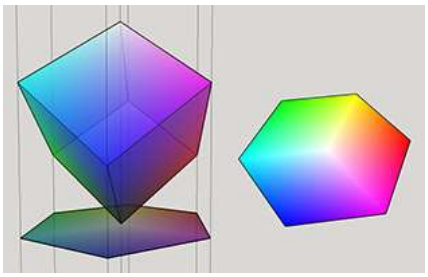


Projection of RGB Cube onto a hexagon

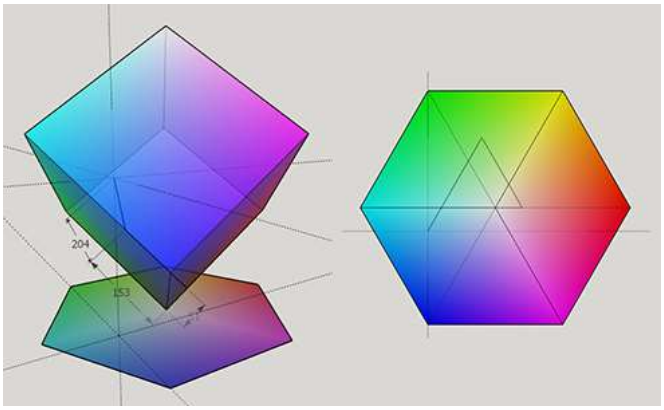
Now that we have the RGB Cube, let's project it onto a hexagon. First, we tilt the cube by 45° on the `x`, and then 35.264° on the `y`. After the second tilt, black corner is at the bottom and the white corner is at the top, and they both pass through the `z` axis.



As you can see, we get the hexagon look we want with the correct hue order when we look at the cube from the top. But we need to project this onto a real hexagon. What we do is draw a hexagon that is in the same size with the cube top view. All the corners of the hexagon corresponds to the corners of the cube and the colors, and the top corner of the cube that is white, is projected onto the center of the hexagon. Black is omitted. And if we map every color onto the hexagon, we get the look at right.



And the position of `51,153,204` on the hexagon would be:



Calculating the Hue

Before we make the calculation, let's define what hue is.

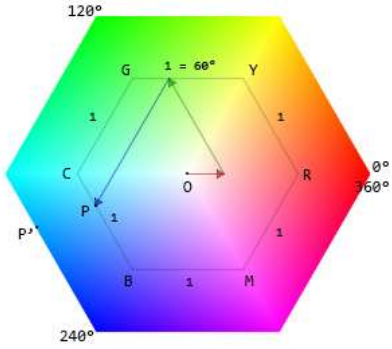
> Hue is roughly the angle of the vector to a point in the projection, with red at 0°.

> ... hue is how far around that hexagon's edge the point lies.

This is the calculation from the HSL and HSV wiki page. We'll be using it in this explanation.

$$H' = \begin{cases} \text{undefined}, & \text{if } C = 0 \\ \frac{G-B}{C} \mod 6, & \text{if } M = R \\ \frac{B-R}{C} + 2, & \text{if } M = G \\ \frac{R-G}{C} + 4, & \text{if } M = B \end{cases}$$
$$H = 60^\circ \times H'$$

Examine the hexagon and the position of `51,153,204` on it.



First, we scale the R, G, B values to fill the [0,1] interval.

```
R = R / 255    R =  51 / 255 = 0.2
G = G / 255    G = 153 / 255 = 0.6
B = B / 255    B = 204 / 255 = 0.8
```

Next, find the `max` and `min` values of `R, G, B`

```
M = max(R, G, B)    M = max(0.2, 0.6, 0.8) = 0.8
m = min(R, G, B)    m = min(0.2, 0.6, 0.8) = 0.2
```

Then, calculate `C` (chroma). Chroma is defined as:

> ... chroma is roughly the distance of the point from the origin.

> Chroma is the relative size of the hexagon passing through a point ...

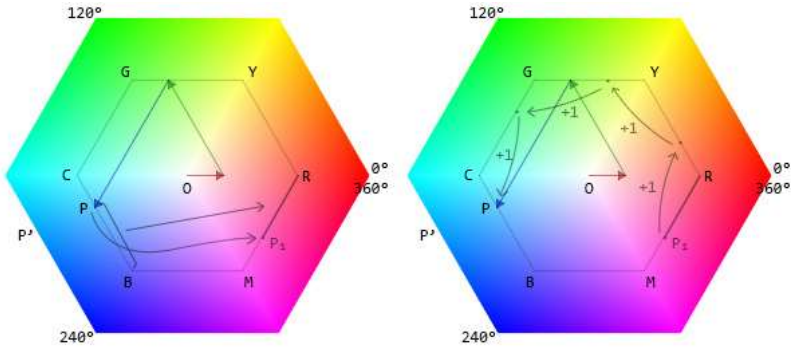
```
C = OP / OP'
C = M - m
C = 0.8- 0.2 = 0.6
```

Now, we have the `R`, `G`, `B`, and `C` values. If we check the conditions, `if M = B` returns true for `51,153,204`. So, we'll be using `H'= (R - G) / C + 4`.

Let's check the hexagon again. `(R - G) / C` gives us the length of `BP` segment.

```
segment = (R - G) / C = (0.2 - 0.6) / 0.6 = -0.6666666666666666
```

We'll place this segment on the inner hexagon. Starting point of the hexagon is R (red) at 0°. If the segment length is positive, it should be on `RY`, if negative, it should be on `RM`. In this case, it is negative `-0.6666666666666666`, and is on the `RM` edge.



Next, we need to shift the position of the segment, or rather `P₁` towars the `B` (because `M = B`). Blue is at `240°`. Hexagon has 6 sides. Each side corresponds to `60°`. `240 / 60 = 4`. We need to shift (increment) the `P₁` by `4` (which is 240°). After the shift, `P₁` will be at `P` and we'll get the length of `RYGCP`.

```
segment = (R - G) / C = (0.2 - 0.6) / 0.6 = -0.6666666666666666
RYGCP   = segment + 4 = 3.3333333333333335
```

Circumference of the hexagon is `6` which corresponds to `360°`. `53,151,204`'s distance to `0°` is `3.3333333333333335`. If we multiply `3.3333333333333335` by `60`, we'll get its position in degrees.

```
H' = 3.3333333333333335
H  = H' * 60 = 200°
```

In the case of `if M = R`, since we place one end of the segment at R (0°), we don't need to shift the segment to R if the segment length is positive. The position of P_1 will be positive. But if the segment length is negative, we need to shift it by 6, because negative value means that the angular position is greater than 180° and we need to do a full rotation.

So, neither the Dutch wiki solution `hue = (g - b) / c;` nor the Eng wiki solution `hue = ((g - b) / c) % 6;` will work for negative segment length. Only the SO answer `hue = (g - b) / c + (g < b ? 6 : 0);` works for both negative and positive values.

JSFiddle: Test all three methods for rgb(255,71,99)

JSFiddle: Find a color's position in RGB Cube and hue hexagon visually

Working hue calculation:

```
console.log(rgb2hue(51,153,204));
console.log(rgb2hue(255,71,99));
console.log(rgb2hue(255,0,0));
console.log(rgb2hue(255,128,0));
console.log(rgb2hue(124,252,0));

function rgb2hue(r, g, b) {
  r /= 255;
  g /= 255;
  b /= 255;
  var max = Math.max(r, g, b);
  var min = Math.min(r, g, b);
  var c   = max - min;
  var hue;
  if (c == 0) {
    hue = 0;
  } else {
    switch(max) {
      case r:
        var segment = (g - b) / c;
        var shift   = 0 / 60;       // R° / (360° / hex sides)
        if (segment < 0) {          // hue > 180, full rotation
          shift = 360 / 60;         // R° / (360° / hex sides)
        }
        hue = segment + shift;
        break;
      case g:
        var segment = (b - r) / c;
        var shift   = 120 / 60;     // G° / (360° / hex sides)
        hue = segment + shift;
        break;
      case b:
        var segment = (r - g) / c;
        var shift   = 240 / 60;     // B° / (360° / hex sides)
        hue = segment + shift;
        break;
    }
  }
  return hue * 60; // hue is in [0,6], scale it up
}
```

Run code snippet Expand snippet

edited Sep 13 '16 at 14:53

answered Aug 25 '16 at 14:03

akinuri

2,982 5 19 46

1 Hi, I am shocked that you answer is ignored or not seen by majority. Thank you so much for explanation I have been researching it for a while and your answer is the best – Alexander Gurevich Jan 17 '17 at 13:21

@AlexanderGurevich I just love to get to the bottom of things, and this was a good study. I wanted to put it out in the open. I'm glad someone have found it useful :) – akinuri Jan 17 '17 at 23:32

Continuing from my comment, the English version looks correct, but I'm not sure what's happening in the Dutch version as I don't understand the WIKI page.

Here is an ES6 version that I made from the English WIKI page, along with some sample data that appear to match the WIKI examples (give or take Javascript's numeric accuracy). Hopefully it may be of use while creating your own function.

```
// see: https://en.wikipedia.org/wiki/RGB_color_model
// see: https://en.wikipedia.org/wiki/HSL_and_HSV

// expects R, G, B, Cmax and chroma to be in number interval [0, 1]
// returns undefined if chroma is 0, or a number interval [0, 360] degrees
function hue(R, G, B, Cmax, chroma) {
  let H;
```

```
  if (chroma === 0) {
    return H;
  }
  if (Cmax === R) {
    H = ((G - B) / chroma) % 6;
  } else if (Cmax === G) {
    H = ((B - R) / chroma) + 2;
  } else if (Cmax === B) {
    H = ((R - G) / chroma) + 4;
  }
  H *= 60;
  return H < 0 ? H + 360 : H;
}

// returns the average of the supplied number arguments
function average(...theArgs) {
  return theArgs.length ? theArgs.reduce((p, c) => p + c, 0) / theArgs.length : 0;
}

// expects R, G, B, Cmin, Cmax and chroma to be in number interval [0, 1]
// type is by default 'bi-hexcone' equation
// set 'luma601' or 'luma709' for alternatives
// see: https://en.wikipedia.org/wiki/Luma_(video)
// returns a number interval [0, 1]
function lightness(R, G, B, Cmin, Cmax, type = 'bi-hexcone') {
  if (type === 'luma601') {
    return (0.299 * R) + (0.587 * G) + (0.114 * B);
  }
  if (type === 'luma709') {
    return (0.2126 * R) + (0.7152 * G) + (0.0772 * B);
  }
  return average(Cmin, Cmax);
}

// expects L and chroma to be in number interval [0, 1]
// returns a number interval [0, 1]
function saturation(L, chroma) {
  return chroma === 0 ? 0 : chroma / (1 - Math.abs(2 * L - 1));
}

// returns the value to a fixed number of digits
function toFixed(value, digits) {
  return Number.isFinite(value) && Number.isFinite(digits) ? value.toFixed(digits) :
value;
}

// expects R, G, and B to be in number interval [0, 1]
// returns a Map of H, S and L in the appropriate interval and digits
function RGB2HSL(R, G, B, fixed = true) {
  const Cmin = Math.min(R, G, B);
  const Cmax = Math.max(R, G, B);
  const chroma = Cmax - Cmin;
  // default 'bi-hexcone' equation
  const L = lightness(R, G, B, Cmin, Cmax);
  // H in degrees interval [0, 360]
  // L and S in interval [0, 1]
  return new Map([
    ['H', toFixed(hue(R, G, B, Cmax, chroma), fixed && 1)],
    ['S', toFixed(saturation(L, chroma), fixed && 3)],
    ['L', toFixed(L, fixed && 3)]
  ]);
}

// expects value to be number in interval [0, 255]
// returns normalised value as a number interval [0, 1]
function colourRange(value) {
  return value / 255;
};

// expects R, G, and B to be in number interval [0, 255]
function RGBdec2HSL(R, G, B) {
  return RGB2HSL(colourRange(R), colourRange(G), colourRange(B));
}

// converts a hexidecimal string into a decimal number
function hex2dec(value) {
  return parseInt(value, 16);
}

// slices a string into an array of paired characters
function pairSlicer(value) {
  return value.match(/../g);
}

// prepend '0's to the start of a string and make specific length
function prePad(value, count) {
  return ('0'.repeat(count) + value).slice(-count);
}

// format hex pair string from value
function hexPair(value) {
  return hex2dec(prePad(value, 2));
}

// expects R, G, and B to be hex string in interval ['00', 'FF']
// without a leading '#' character
function RGBhex2HSL(R, G, B) {
  return RGBdec2HSL(hexPair(R), hexPair(G), hexPair(B));
}

// expects RGB to be a hex string in interval ['000000', 'FFFFFF']
// with or without a leading '#' character
function RGBstr2HSL(RGB) {
  const hex = prePad(RGB.charAt(0) === '#' ? RGB.slice(1) : RGB, 6);
```

```
  return RGBhex2HSL(...pairSlicer(hex).slice(0, 3));
}

// expects value to be a Map object
function logIt(value) {
  console.log(value);
  document.getElementById('out').textContent += JSON.stringify([...value]) + '\n';
};

logIt(RGBstr2HSL('000000'));
logIt(RGBstr2HSL('#808080'));
logIt(RGB2HSL(0, 0, 0));
logIt(RGB2HSL(1, 1, 1));
logIt(RGBdec2HSL(0, 0, 0));
logIt(RGBdec2HSL(255, 255, 254));
logIt(RGBhex2HSL('BF', 'BF', '00'));
logIt(RGBstr2HSL('008000'));
logIt(RGBstr2HSL('80FFFF'));
logIt(RGBstr2HSL('8080FF'));
logIt(RGBstr2HSL('BF40BF'));
logIt(RGBstr2HSL('A0A424'));
logIt(RGBstr2HSL('411BEA'));
logIt(RGBstr2HSL('1EAC41'));
logIt(RGBstr2HSL('F0C80E'));
logIt(RGBstr2HSL('B430E5'));
logIt(RGBstr2HSL('ED7651'));
logIt(RGBstr2HSL('FEF888'));
logIt(RGBstr2HSL('19CB97'));
logIt(RGBstr2HSL('362698'));
logIt(RGBstr2HSL('7E7EB8'));

<pre id="out"></pre>
```

Run code snippet Expand snippet

edited Aug 24 '16 at 18:52

answered Aug 24 '16 at 12:45

Xotic750

14.8k 4 36 61

I really appreciate the effort, but this seems much more complicated than the one I've already written :) I've been reading the wiki pages over and over again, and creating the rgb cube-to-hexagon projection in a 3d software. I'm really close to understanding *everything* in the calculation. I'll post my understanding sometime soon. (Sorry for the late reply :) – akinuri Aug 24 '16 at 21:37

I don't know about much more complicated (sure, in all it can do a few more things than your example), but basically it's the same but broken down into smaller testable and reusable functions rather than a single function. I could probably do it in a single line of code, but that wouldn't be very readable, reusable or maintainable. Oh and I used ES6 rather than just ES3, I know you didn't ask for any code but I needed to dust off some rust and I thought that I may as well share my tinkering with you in an answer rather than just the comment. :) – Xotic750 Aug 24 '16 at 21:53

I've posted my answer (if you haven't seen it already). It's incomplete right now. Updated it once. Gonna update it again. I'd like your feedback (I might be doing it wrong, idk :) – akinuri Aug 26 '16 at 14:29

It's a very pretty description of what needs to be calculated, but so far doesn't answer the actual question that you posted. I'm kind of thinking that perhaps your questions and answer were better suited to mathoverflow.net as it doesn't really seem to have much to do with the programming aspect, but a great deal to do with mathematics. – Xotic750 Aug 27 '16 at 9:37

It's still not done yet. I'll add the last part where I'll talk about the calculation. I liked this conversion thing so much that I wanted to be thorough with it. I'm sure it'll be useful for future visitors. – akinuri Aug 27 '16 at 17:47

Hue in HSL is like an angle in a circle. Relevant values for such angle reside in the 0..360 interval. However, negative values might come out of the calculation. And that's why those three formulas are different. They do the same in the end, they just handle differently the values outside the 0..360 interval. Or, to be precise, the 0..6 interval which is then eventually multiplied by 60 to 0..360

`hue = (g - b) / c;  // dutch wiki` does nothing with negative values and presumes the subsequent code can handle negative H values.

`hue = ((g - b) / c) % 6; // eng wiki` uses the `%` operator to fit the values inside the 0..6 interval

`hue = (g - b) / c + (g < b ? 6 : 0); // SO answer` takes care of negative values by adding +6 to make them positive

You see that these are just cosmetic differences. Either the second or the third formula will work fine for you.

answered Aug 24 '16 at 12:59

Matey

932 3 7

I don't think the second will work for both positive and negative values. I don't see any scenario where `(g - b) / c)` is greater than 6. It should always be <= 1. So mod seems redundant. Only the third formula works as expected. See my updated answer. – akinuri Aug 29 '16 at 19:09

@akinuri : `mod` for negative values of the dividend increases the dividend by the divisor until it's positive. Which is exactly the same as the third formula. – Matey Sep 13 '16 at 15:56

See this jsfiddle. `en_rgb2hue()` uses the mod calculation. It does not give the correct value. – akinuri Sep 13 '16 at 16:16

My bad. There are obviously two worlds regarding how the negative values should be handled by `%`. Thanks for correcting me. – Matey Sep 14 '16 at 7:48