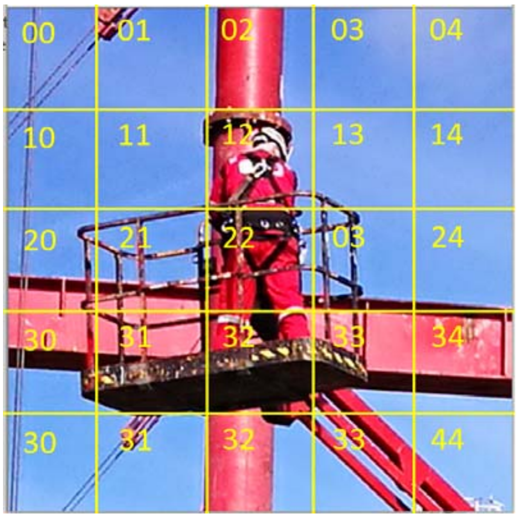
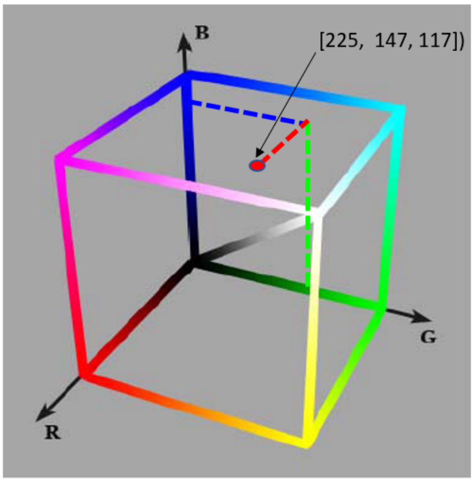
Windowing

Method

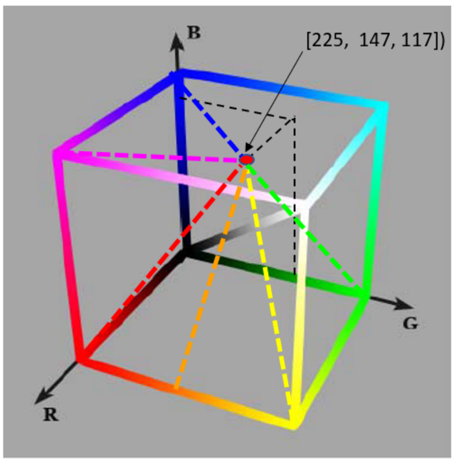
1. The target area is segmented in sub-targets. (e.g. In below picture we use a 5x5 grid)



2. For each segment we calculated the mean BGR. (e.g. For sub-target 00 above, the mean is [225, 147, 117])

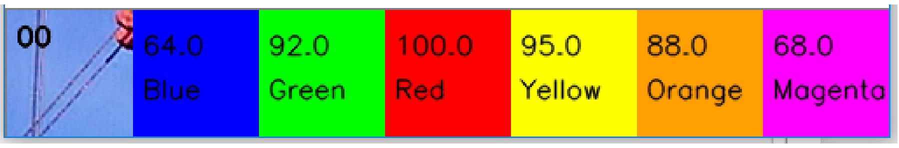


3. For each segment we calculate the Euclidean distance to each or our six safety colors:




```
Safety_colors_BGR = {
    'Blue' : (255, 0, 0),
    'Green' : (0, 255, 0),
    'Red' : (0, 0, 255),
    'Yellow' : (0, 255, 255),
    'Orange' : (0, 160, 255),
    'Magenta' : (255, 0, 255),
}
```

4. We rank the safety colors in a scale 100 to 1. Rank 100 means high contrast (the most far apart Safety Color) and 1 means low contrast (same color as the mean color of the target)
Below is the ranking for sub-target 00)



5. We sum all rankings by color (in this example 25 sub-targets -> 25 values per color)

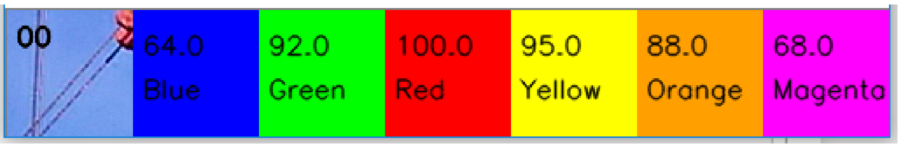
01 [64. 92. 100. 95. 88. 68.]
02 [126. 182. 200. 189. 176. 136.]
03 [211. 282. 267. 268. 237. 194.]
04 [273. 371. 367. 361. 324. 261.]
:
:
24 [1835. 2267. 2088. 2172. 1874. 1726.]
25 [1919. **2367.** 2188. 2259. 1955. 1793.]

6. The previous step produces the overall most distant color; thus, the most conspicuous safety color. Greater distance → greater contrast (Safety color more conspicuous). (e.g. for the above target the optimal safety color is Green)

7.Conclusion
Overall the method works.

Main Issues and Improvements

Issue 1: The safety color ranking for each of the 25 sub-targets is shown in the last page. We notice that a highly ranked safety color for the sky is the color red (See sub target 00). Similarly, a highly rank contrast color for the red beams is blue (see Sub-target 12).



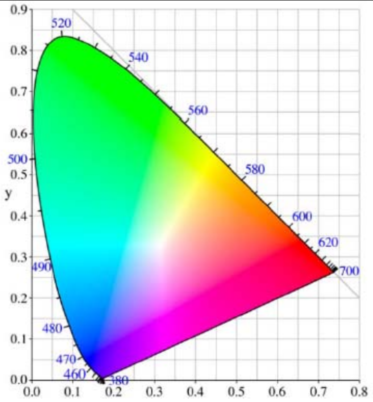
We have identified two approaches can reduce/eliminated this drawback:

Issue 1 – Approach A
Reduce/eliminate the intrinsic inability of the RGB color space to fit human color perception. (Is this statement correct?) A few ways to achieve that:

A.1 Weight RGB values to fit human perception

e.g. $\sqrt{2 \times \Delta R^2 + 4 \times \Delta G^2 + 3 \times \Delta B^2}$, of other weighting methods.

A.2. Instead of RGB, use color spaces specific for modelling the human color perception. For example, CIELab. (returning to our example, green in the CIELab space is twice as far as red)



CIE76

$$\Delta E_{ab}^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}.$$

CIE94

$$\Delta E_{94}^* = \sqrt{\left(\frac{\Delta L^*}{k_L S_L}\right)^2 + \left(\frac{\Delta C_{ab}^*}{k_C S_C}\right)^2 + \left(\frac{\Delta H_{ab}^*}{k_H S_H}\right)^2}$$

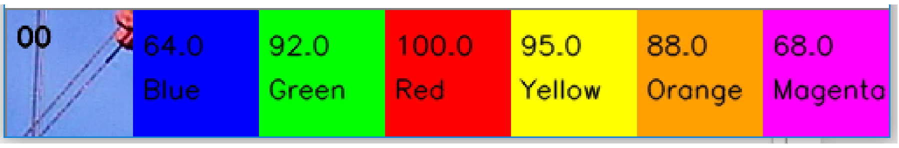
where:

$$\Delta L^* = L_1^* - L_2^*$$
$$C_1^* = \sqrt{a_1^{*2} + b_1^{*2}}$$
$$C_2^* = \sqrt{a_2^{*2} + b_2^{*2}}$$
$$\Delta C_{ab}^* = C_1^* - C_2^*$$
$$\Delta H_{ab}^* = \sqrt{\Delta E_{ab}^{*2} - \Delta L^{*2} - \Delta C_{ab}^{*2}} = \sqrt{\Delta a^{*2} + \Delta b^{*2} - \Delta C_{ab}^{*2}}$$
$$\Delta a^* = a_1^* - a_2^*$$
$$\Delta b^* = b_1^* - b_2^*$$
$$S_L = 1$$
$$S_C = 1 + K_1 C_1^*$$
$$S_H = 1 + K_2 C_1^*$$

CIE200 formulas etc

Issue 1 – Approach B

Second approach is to penalize colors that are nearer to a sub-target's mean.
For example, in Sub-target 00, we can penalize blue and magenta by reducing their Euclidian distance by 50%. Their rank (1-100) will then reduce to 32 and 34.



Similarly, for Sub-target 12, we can penalize Red and Orange. Their rank will be reduced to 34.5 and 32

It is possible to use both of the above approached to solve Issue 1; however, since the main objective of the project is to examine how effective is the concept of selecting an optimal safety color, we believe that we should proceed only with solution 2 which is the easiest and most resilient.

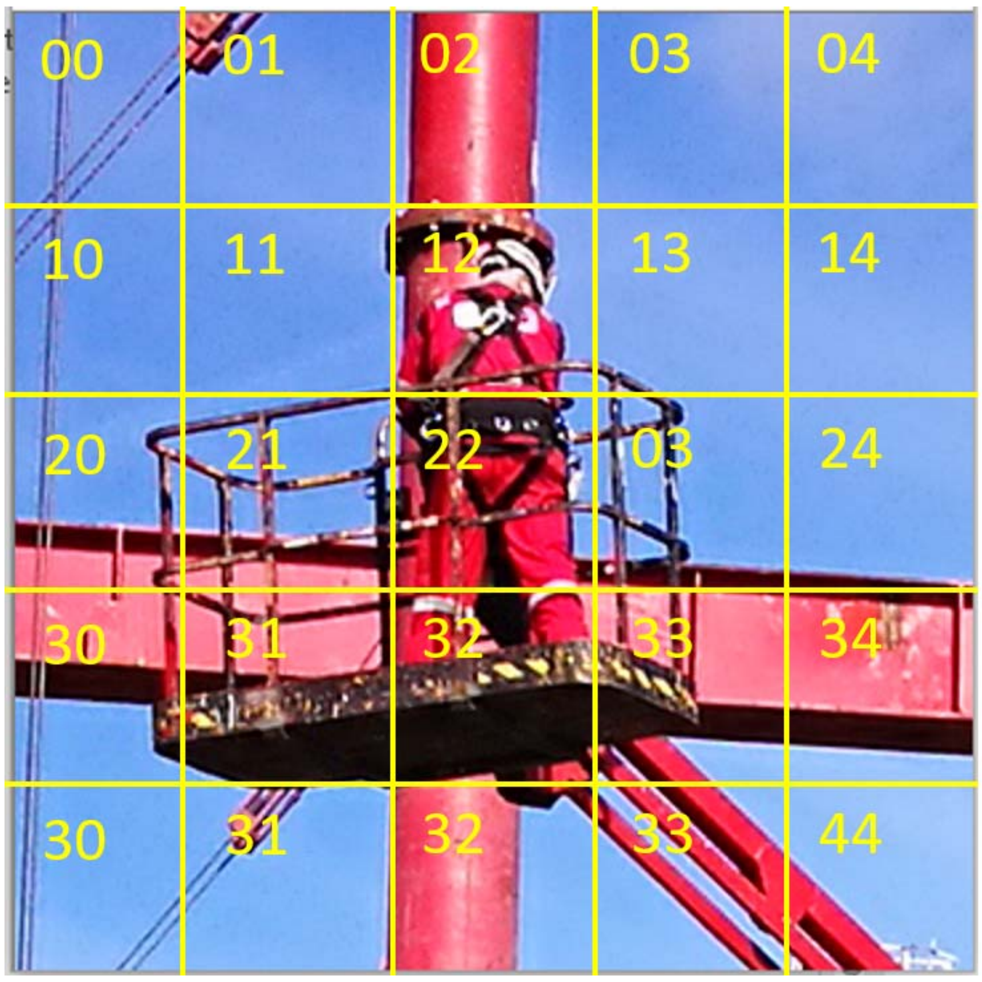
Issue 2

The light conditions of the image may result to altered colors (for example deep saturated red may look as light red to pink). Red may look as very lark red (almost black)

There are ways to process the image and make our method more resilient to the light/saturation of the specific image such as:
- normalization R/(Sum of RGB), G/(Sum of RGB), B/(Sum of RGB)
- Transform the picture to a standardized (Windows 20-color pallet or other pallet). For each pixel use HSL to get H and then transform the closest values on the pallet

- …..many other methods….

We will not address Issue 2. It is not a major issue to the objective of the project (proof of concept). This issue can be address in possible future commercial version.



00	64.0 Blue	92.0 Green	100.0 Red	95.0 Yellow	88.0 Orange	68.0 Magenta
01	62.0 Blue	90.0 Green	100.0 Red	94.0 Yellow	88.0 Orange	68.0 Magenta
02	85.0 Blue	100.0 Green	67.0 Red	79.0 Yellow	61.0 Orange	58.0 Magenta
03	62.0 Blue	89.0 Green	100.0 Red	93.0 Yellow	87.0 Orange	67.0 Magenta
04	69.0 Blue	92.0 Green	100.0 Red	90.0 Yellow	85.0 Orange	67.0 Magenta
10	58.0 Blue	88.0 Green	100.0 Red	95.0 Yellow	88.0 Orange	68.0 Magenta
11	61.0 Blue	88.0 Green	100.0 Red	93.0 Yellow	88.0 Orange	68.0 Magenta
12	89.0 Blue	100.0 Green	69.0 Red	86.0 Yellow	64.0 Orange	72.0 Magenta
13	68.0 Blue	90.0 Green	100.0 Red	89.0 Yellow	85.0 Orange	67.0 Magenta
14	67.0 Blue	90.0 Green	100.0 Red	89.0 Yellow	85.0 Orange	66.0 Magenta
20	77.0 Blue	100.0 Green	98.0 Red	97.0 Yellow	86.0 Orange	73.0 Magenta
21	79.0 Blue	100.0 Green	98.0 Red	100.0 Yellow	86.0 Orange	79.0 Magenta
22	92.0 Blue	100.0 Green	54.0 Red	96.0 Yellow	68.0 Orange	87.0 Magenta
23	68.0 Blue	92.0 Green	100.0 Red	97.0 Yellow	88.0 Orange	75.0 Magenta
24	67.0 Blue	89.0 Green	100.0 Red	90.0 Yellow	86.0 Orange	68.0 Magenta
30	87.0 Blue	100.0 Green	81.0 Red	89.0 Yellow	72.0 Orange	75.0 Magenta
31	98.0 Blue	100.0 Green	70.0 Red	100.0 Yellow	73.0 Orange	97.0 Magenta
32	89.0 Blue	90.0 Green	64.0 Red	100.0 Yellow	76.0 Orange	100.0 Magenta
33	94.0 Blue	100.0 Green	67.0 Red	83.0 Yellow	61.0 Orange	75.0 Magenta
34	93.0 Blue	100.0 Green	65.0 Red	78.0 Yellow	58.0 Orange	69.0 Magenta
40	65.0 Blue	87.0 Green	100.0 Red	89.0 Yellow	85.0 Orange	68.0 Magenta
41	68.0 Blue	90.0 Green	100.0 Red	90.0 Yellow	85.0 Orange	69.0 Magenta
42	89.0 Blue	100.0 Green	75.0 Red	76.0 Yellow	62.0 Orange	59.0 Magenta
43	84.0 Blue	100.0 Green	80.0 Red	84.0 Yellow	69.0 Orange	63.0 Magenta
44	84.0 Blue	100.0 Green	100.0 Red	87.0 Yellow	81.0 Orange	67.0 Magenta