Determination of Pedestrian Mannequin Clothing Color for the Evaluation of Image Recognition Performance of Pedestrian Pre-Collision Systems

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ABSTRACT

Pedestrian Pre-Collision Systems (PPCS) for helping avoid or mitigate pedestrian crashes have been equipped on many vehicles [1]. At present, there is no common standard for the performance evaluation of PPCSs. The Transportation Active Safety Institute (TASI) at Indiana University-Purdue University-Indianapolis with support from Toyota's Collaborative Safety Research Center (CSRC) has been studying the various issues to support the effort of developing such a standard. An important component in the PPCS evaluation is the development of a standard mannequin. This paper describes the approaches used to determine the color of the clothing on the mannequins based on the data obtained from the TASI 110 car one year naturalistic driving data collected in the greater Indianapolis area in USA.

1. Introduction

Pedestrian Pre-Collison System (PPCS) is an active safety system component to help avoid or mitigate the collision with pedestrians [1]. Many automotive companies have been developing PPCSs and have started to equip them in their vehicles [2]. The performance of different PPCS systems varies significantly. Many research groups and government agencies are actively studying various methods for the evaluation of PPCSs [3]. At present, there is no common evaluation standard for PPCS. The Transportation Active Safety Institute (TASI) at Indiana University-Purdue University-Indianapolis has been conducting research related to the establishment of such a standard with the support from Toyota Collaborative Safety Research Center (CSRC). Many PPCS use mono or stereo cameras for pedestrian detection which is an important part of the PPCS. One factor that may significantly affect the performance of the pedestrian detection is the color of the clothing worn by the mannequins. In order to define testing scenarios for evaluating and comparing PPCS systems, representative clothing colors for both adult and children needs to be selected to dress the dummies used in PPCS testing. This paper describes a method for determining the clothing colors for adult and child mannequins in the United States for PPCS evaluation based on pedestrian cloth color data obtained from the TASI 110 car one year naturalistic driving study.

The paper is organized as follows. Section 2 describes the process of getting the pedestrian upper and lower cloth colors. Section 3 explains the process of dividing the color space into color regions and selecting the representative color. Sections 4 and 5 are discussion and conclusion, respectively.

2. Pedestrian cloth color data collection and preprocessing

Many PPCS use mono or stereo cameras for pedestrian detection. One factor that may significantly affect the effectiveness of a PPCS is the color of the clothing worn by the pedestrians. In order to define testing scenarios for evaluating and comparing the PPCSs, representative clothing colors for both adult and children need to be selected for the performance evaluation. The color of the mannequin's clothing is one of the many variables that can affect the performance of PPCSs. To limit the number of tests needed for PPCS performance evaluation, it is imperative to select a standard color of clothing that represents US adult pedestrians and a standard color of clothing that represents US children pedestrians. This problem involves two issues, the first is to get the data and d3escribe the pedestrians clothing color distributions, and the second is to choose specific representative colors.

From 2012 to 2013, TASI equipped 110 cars with systems capable of recording naturalistic driving data, and collected naturalistic driving data in the greater Indianapolis Indiana USA area. The purpose was to study the pedestrian behaviors in various conditions. An HD CMOS camera with GPS and G-sensor was installed on each vehicle to gather video of what the driver would see out of the front windshield. Each car collected video data for one year amounting to 100 TB of video data. 60,000 Pedestrians were identified in the video, then the clothing colors of the pedestrians were recorded by choosing one point on the pedestrian's upper body and one point at pedestrian's lower body. The RGB values at these points were recorded.

By examining the clothing colors on the pedestrian images, it was noticed that the color of the clothing is not only affected by the fabric itself, but also affected by brightness of the environment. The same clothing appears darker in a darker environment. The brightness of the environment is affected by weather, the time of the day, and the shade under a tree or building. Since these factors are controllable in the PPCS testing, only the true colors of the clothes is useful for this study. Therefore, around 8,439 pedestrian videos were manually selected from the 60,000 pedestrians such that the pedestrians in the frame were well lit by sun light during clear weather and not under any shade. Then, RGB values of the upper clothes and lower clothes were extracted.

The upper clothing colors of adult pedestrians are shown in a 3d RGB gamut space (Figure 1). The RGB gamut space is modeled as a cube with three axes Red, Blue and Green. The value range of each axis is normalized between 0 and 1. Black is at the corner of the cube that all R, G, B values are zero and white is at the opposite corner with all RGB values equal to 1. Each black dot on the diagram represents the cloth color of a pedestrian.

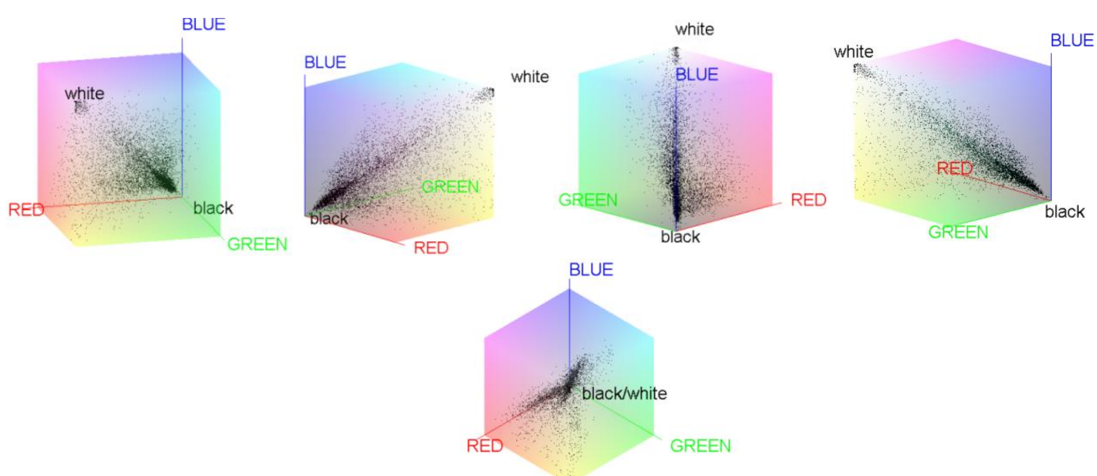


Figure 1. The colors of the top cloth of adult pedestrians plotted in five viewing angles in the RGB space.

These 3d gamut diagrams show that (1) the adult upper clothing colors are concentrated around the diagonal from the black to white axis, and (2) the colors tend to have a larger variance (span) on the axis when moving from black to white (This is reasonable due to Webber's law [4]).

3. Selection of the representative colors

The first approach for selecting the representative color is to find a color that has minimum sum of the mean square error to all the color points in the pedestrian cloth color poll. However, due to the shape of the distribution of the pedestrian's cloth value, the resulting color is between gray and black for upper and lower cloths of both adults and children. It is concluded that this approach is not optimal.

The second approach is to divide the 3D space into seven color regions and the find which regions cover the most number of pedestrians. The seven regions are black-white, red, red-green, green, green-blue, blue, and blue-red. The boundaries of the seven color regions are determined according to the ratio of the two adjacent color values, as described as follows,

Black/White region: $(R/B \leq 1+\Delta)$ && $(B/R \leq 1+\Delta)$ && $(B/G \leq 1+\Delta)$ &&
$(G/B \leq 1+\Delta)$ && $(R/G \leq 1+\Delta)$ && $(G/R \leq 1+\Delta)$

Red region: $((R+G)/2 \geq B)$ && $((R+B)/2 \geq G)$ && $((R/G > 1+\Delta) \parallel (R/B > 1+\Delta))$
Blue region: $((B+R)/2 \geq G)$ && $((B+G)/2 \geq R)$ && $((B/R > 1+\Delta) \parallel (B/G > 1+\Delta))$
Green region: $((G+B)/2 \geq R)$ && $((G+R)/2 \geq B)$ && $((G/B > 1+\Delta) \parallel (G/R > 1+\Delta))$

Magenta region: $((R+G)/2 < B)$ && $((G+B)/2<R)$ && $((R/G > 1+\Delta) \parallel (B/G > 1+\Delta))$
Cyan region: $((B+R)/2 < G)$ && $((R+G)/2<B)$ && $((B/R > 1+\Delta) \parallel (G/R > 1+\Delta))$
Yellow region: $((G+B)/2 < R)$ && $((B+R)/2<G)$ && $((G/B > 1+\Delta) \parallel (R/B > 1+\Delta))$

Where Δ defines the boundaries of the black-white region around the black-white diagonal line. The value of Δ is chosen as between 0.1 and 0.2. These seven regions are shown in Figure 2.

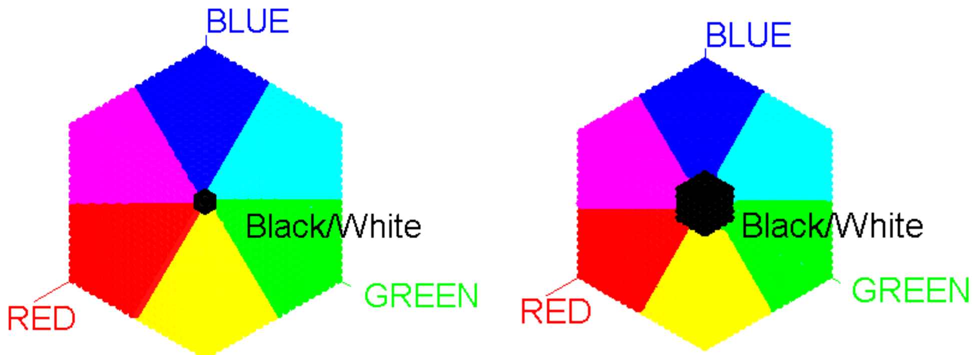


Figure 2. Seven color regions. (Left: Δ = 0.1; Right: Δ = 0.3)

To be able to distinguish the shade of the color, each of these seven regions is divided into 3 sub regions according to the color intensity. The intensity division is based on the following method,

Dark shade: $(R \leq 1/3)$ && $(G \leq 1/3)$ && $(B \leq 1/3)$
Medium shade: $(1/3 < R \leq 2/3)$ && $(1/3 < G \leq 2/3)$ && $(1/3 < G \leq 2/3)$
Light shade: $(R > 2/3)$ && $(G > 2/3)$ && $(G > 2/3)$

An example of 3 shades within the white-black region is shown in Figure 3. Therefore, a total of 21 non-overlapping regions completely cover the 3D color space is generated (Figure 4).

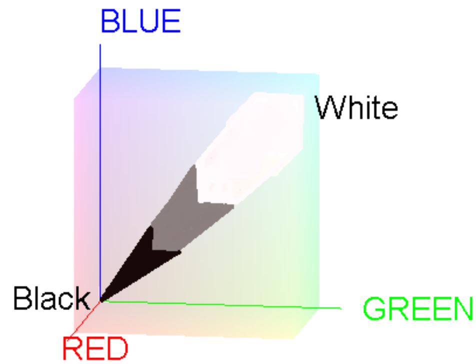


Figure 3. An example of 3 color shades in a region.

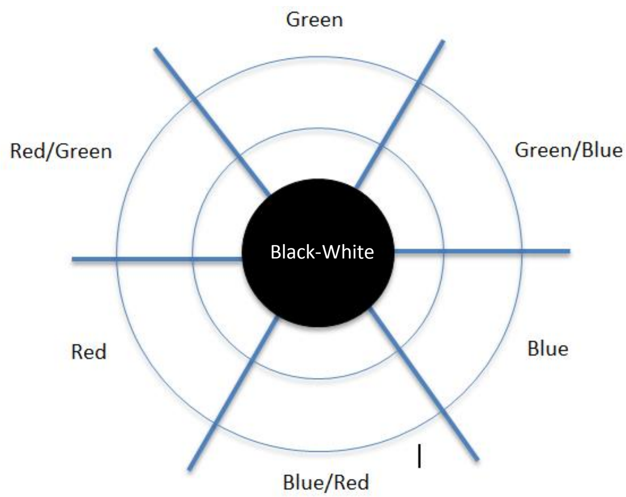


Figure 4. 21 color regions in the color space. The Black-White regions are divided in the axis perpendicular to the figure.

In order to illustrate the distribution for clothing colors in a visual friendly way, a chromaticity diagram is introduced. A chromaticity diagram can define the hue and colorfulness [5] [6] regardless of its luminance by compressing its luminance information to 2-dimentions. In this method, the luminance is less important than hue since the frame selected guarantees that colors can be interpreted correctly. The 2D chromaticity diagram source code is inspired from ECE 637 from Professor Bouman, Purdue University [7].The outer red line of the chromaticity diagram represent all the color that human can perceive [8], the CIE 1931 standard and Rec.709 standard are part of all perceivable color.

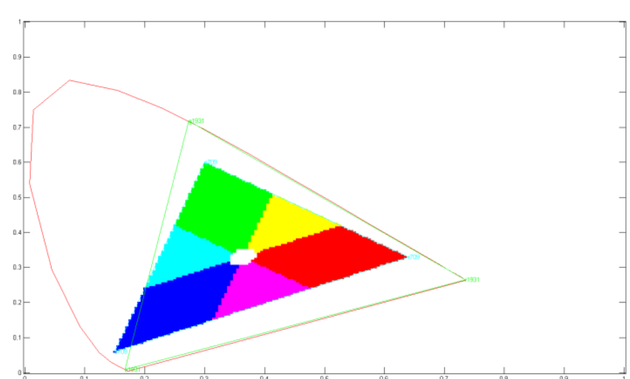
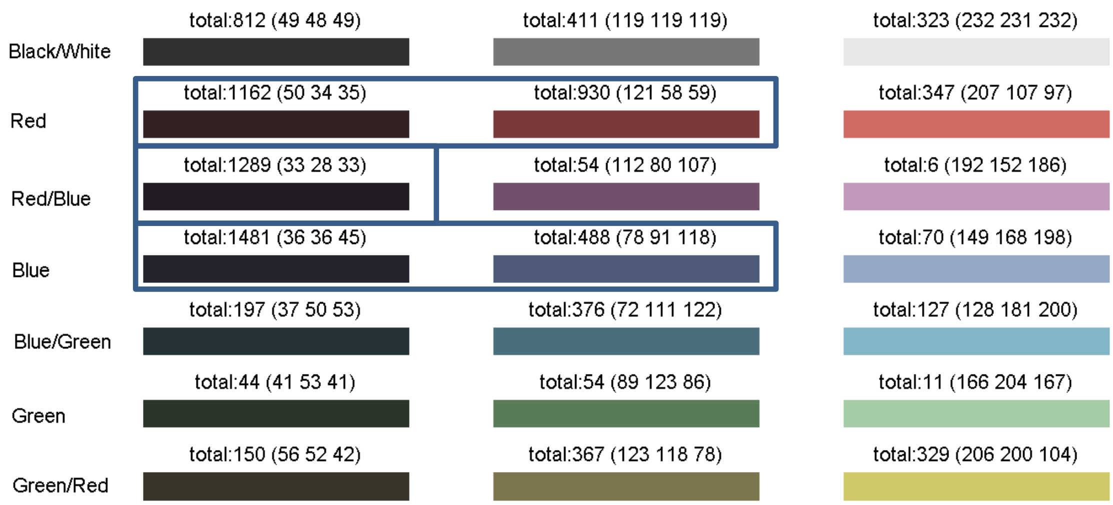


Figure 5. 2D chromaticity diagram of the color of children upper cloths.

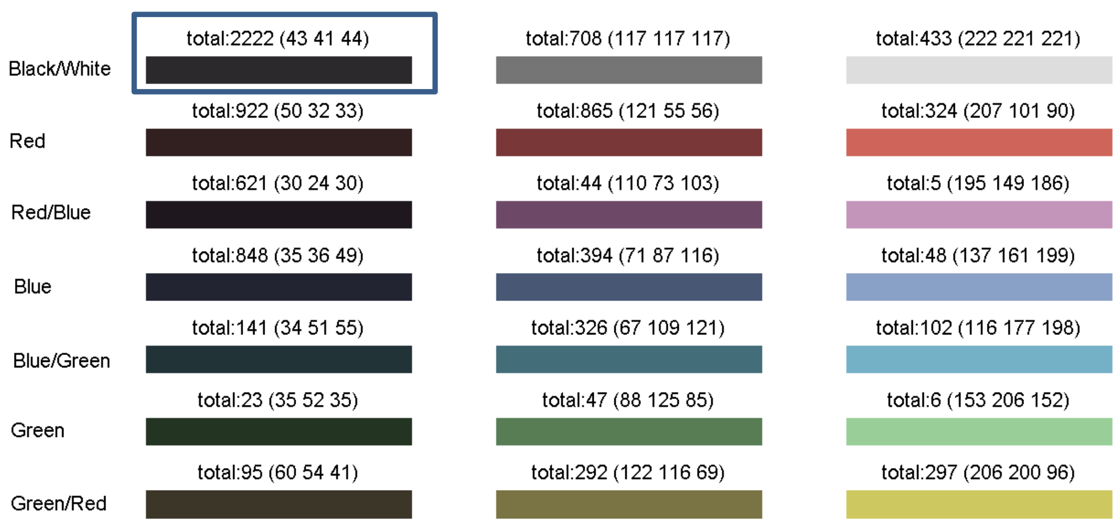
A. Adult upper cloth color

The number of the adult upper cloth and lower cloth in each color region is shown in Figure 6 and 7, respectively. The three numbers in the parentheses are the average RGB values of clothing colors in that region, respectively.

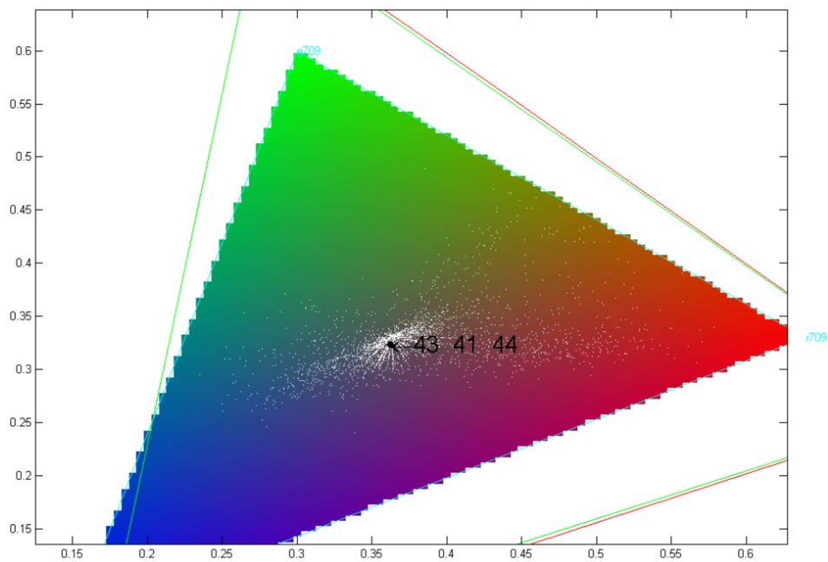
When Δ=0.1, dark/medium red, dark red/blue, and dark/medium blue are the most popular colors for adult upper cloth (see Figure 6a). Since there are more than one basic color region included, the color population in Δ=0.2 cases are checked. When Δ is increased to 0.2, a significant number of upper cloth from dark red, dark red/blue, and dark blue regions is moved to dark black-white region so that black becomes the dominate population(see Figure 6(b)). Therefore, the black color (RGB = 43, 41, 44) is selected as the adult upper cloth color. The corresponding point is shown as a black dot in Figure 6(c).



(a) Adult upper cloth. Δ = 0.1



(b) Adult upper cloth. Δ= 0.2

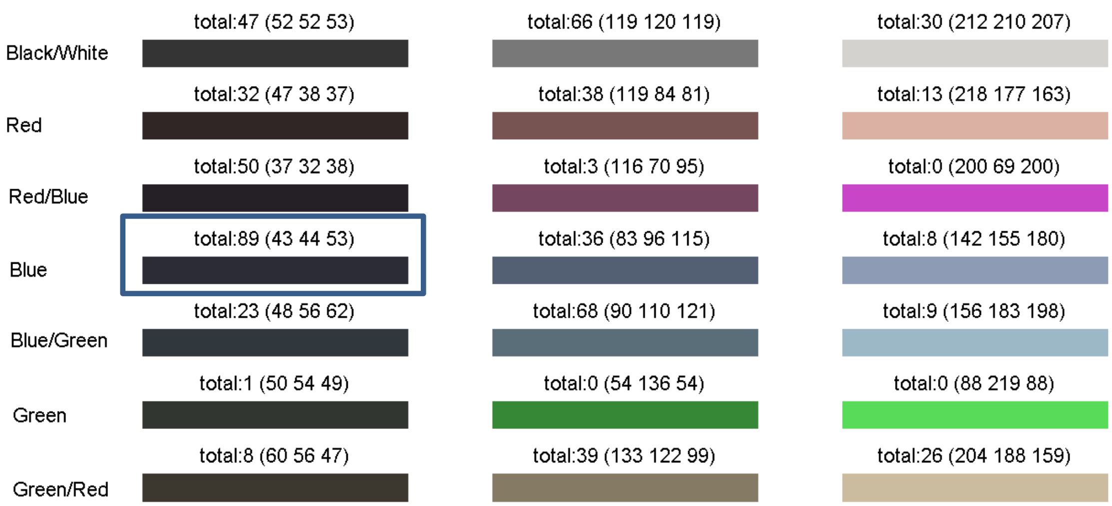


(c) 2D chromaticity diagram of the color of adult upper cloths. Black dot shows the selected color.

Figure 6. The selection of the mostly wore adult upper cloth color based on TASI 110 car naturalistic driving data.

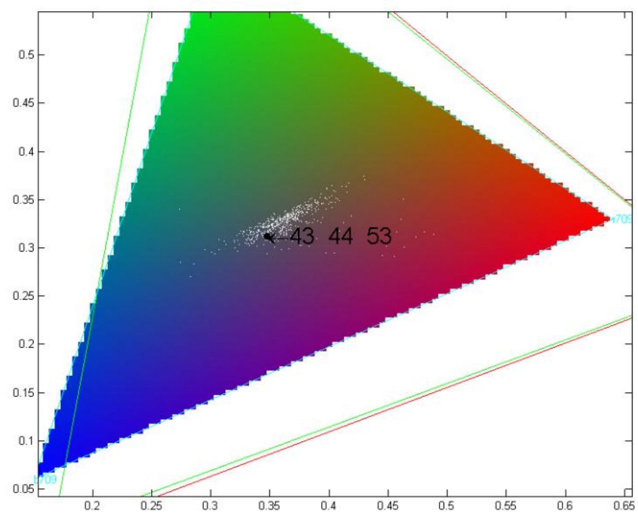
B. Adult lower cloth color

The number of adult lower clothing colors in each color region is shown in Figure 7. When Δ=0.1, dark blue (43, 44, 53) is significantly more favorable than other colors. Therefore, dark blue color (RGB= 43, 44, 53) is selected for adult lower cloth color. The corresponding point is shown as a black dot in Figure 7(c).



(a) Adult lower part Δ= 0.1

(b) Adult lower part Δ= 0.2

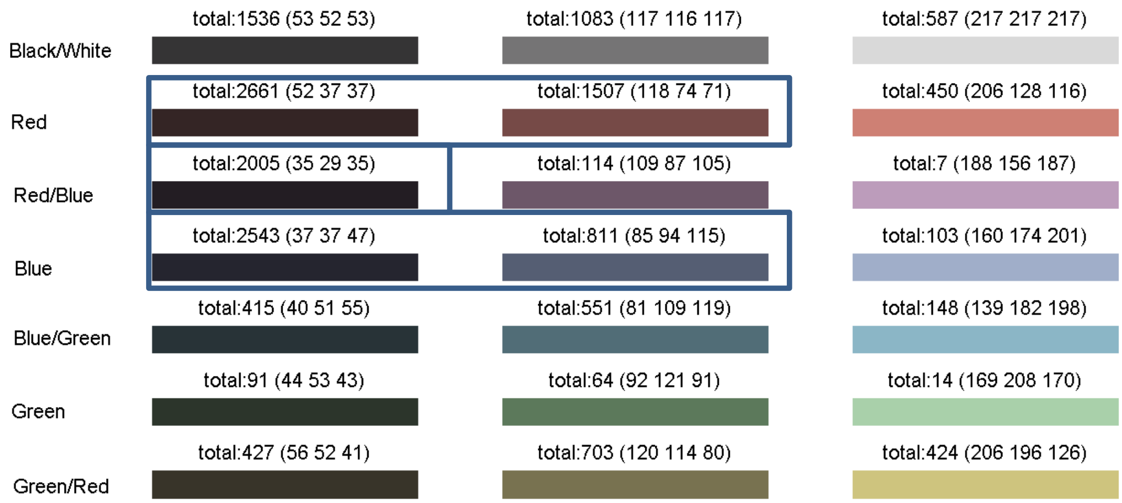


(c) 2D chromaticity diagram of the color of adult lower cloths. Black dot shows the selected color.

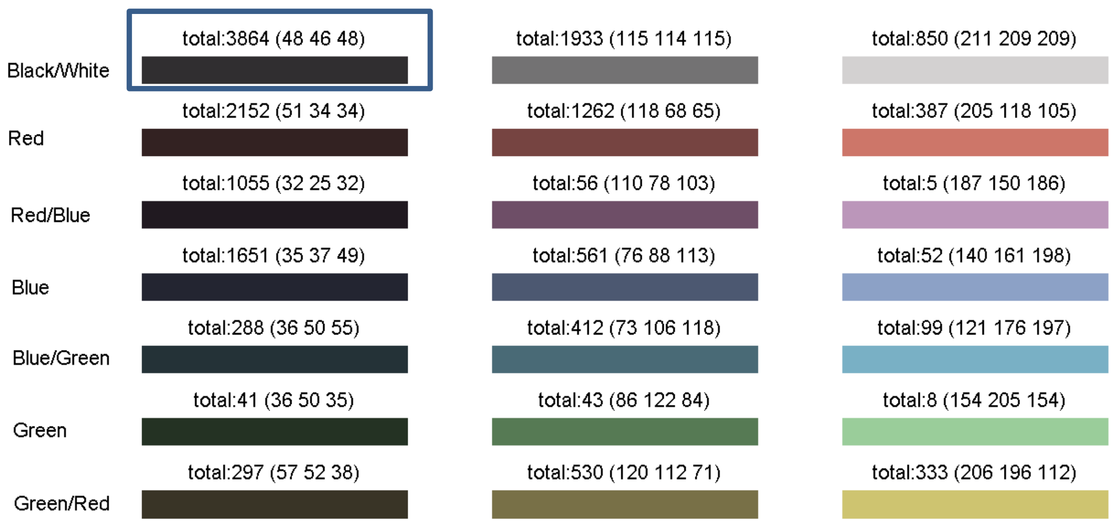
Figure 7. The selection of the mostly wore adult lower cloth color based on TASI 110 car naturalistic driving data.

C. Child upper cloth color

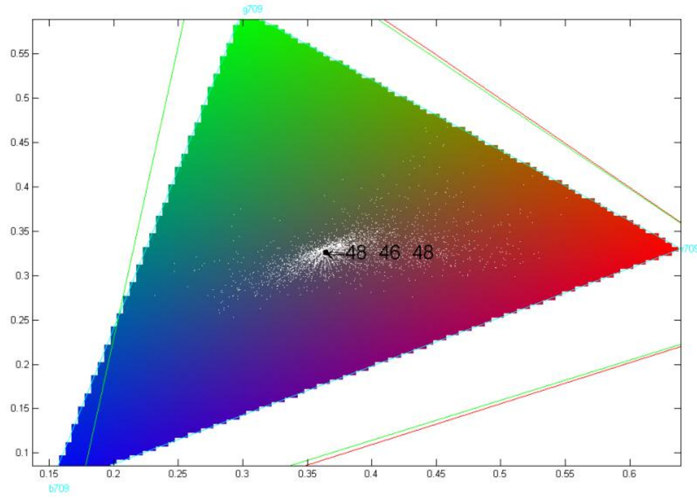
The number of the child upper cloth colors in each color region is shown in Figures 8. When Δ=0.1, dark/medium red, dark red/blue, and dark/medium blue were the most popular colors for adult upper clothing. Since there is more than one pure color region having high population, the color population in Δ=0.2 cases is checked. When Δ is increased to 0.2, a significant number of the population from dark red, dark red/blue, and dark blue regions are moved to dark black-white region so that black becomes the dominate population. Therefore, the black color (RGB = 48, 46, 48) is selected as the child upper clothing color. The corresponding point is shown as a black dot in Figure 8(c).



(a) Children upper cloth. part $\Delta = 0.1$



(b) Children upper cloth. $\Delta = 0.2$

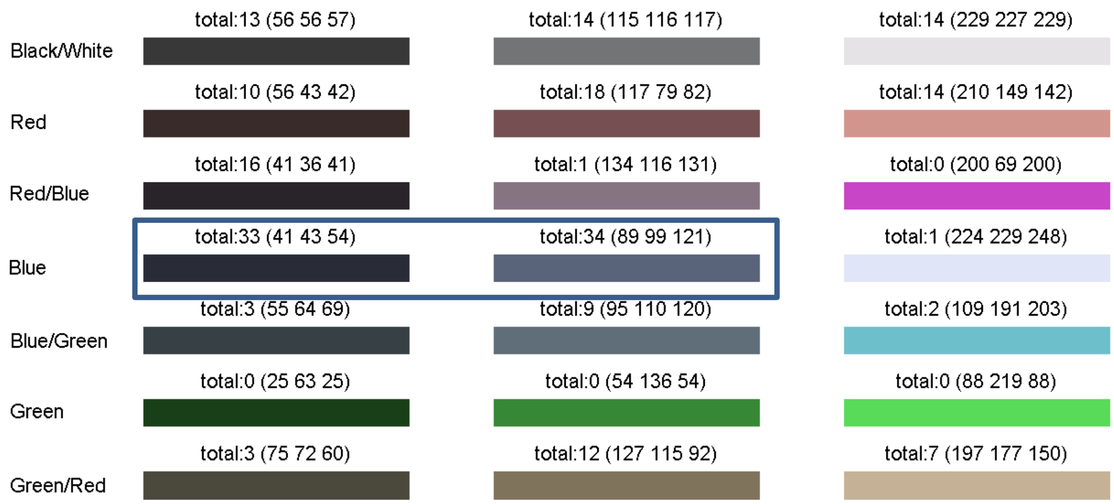


(c) 2D chromaticity diagram of the color of child upper cloths. Black dot shows the selected color.

Figure 8. The selection of the mostly wore children upper cloth color based on TASI 110 car naturalistic driving data.

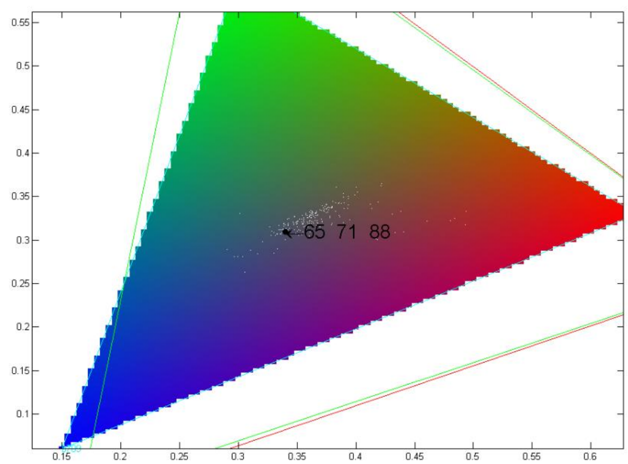
D. Chile lower cloth color

The number of the child lower clothing colors in each color region is shown in Figure 9. Since there are close counts in the dark blue and medium blue regions, the average color (65, 71, 88) of these two blue shades is selected to represent the child lower cloth color. The corresponding point is shown as a black dot in Figure 9(c).



(a) Children lower part Δ= 0.1

(b) Children lower part Δ= 0.2



(c) 2D chromaticity diagram of the color of child lower cloths. Black dot shows the selected color.

Figure 10. The selection of the mostly representative child lower cloth color based on TASI 110 car naturalistic driving data

Summary of cloth colors

The representative the upper cloth color for adult is black (RGB=43, 41, 44)
The representative the lower cloth color for adult is deep dark blue (RGB=43, 44, 53)
The representative the upper cloth color for children is black (RGB=48, 46, 48)
The representative of the lower cloth color for children is medium blue. (RGB=65, 71, 88)

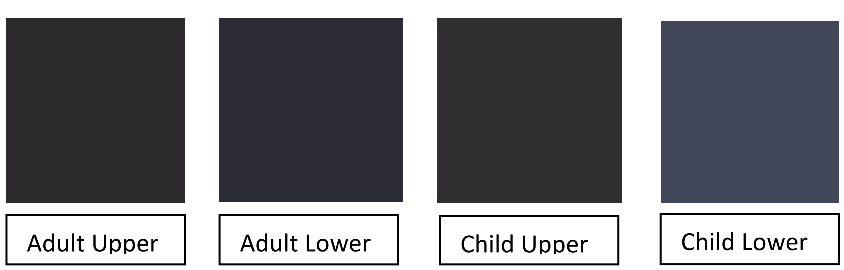


Figure 11. The representation of upper/lower adult and upper/lower children cloth color from left to right.

4. Discussion

The goal in this paper is to select one set of colors for dressing the mannequins for PPCS evaluation. The proposed method is to determine the color based on the popularity of the colors seen from video cameras. It is well known that lighting affects the perceived color. Even through the data preparation tried to remove the lighting influences, the color seen in the image are still darker than the original color. There are other possible ways to consider the clothing color, such as contrast to the background. Contrast base study is currently ongoing and will be reported in the future.

5. Conclusion

A method for finding the representing upper and lower clothing colors for both child and adult mannequins is described in this paper. The paper is based on the pedestrian data collected from TASI 110 car one year naturalistic driving in Greater Indianapolis area in USA. This data can be considered as an accurate representation for the whole Midwest region in USA. The method can be applied to additional pedestrian clothing color data from other naturalistic driving studies.

Acknowledgments

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