The Simplification of CAM16 Used in Google's Monet

Note: All the numbers were rounded to 17 significant digits (which was done in the last steps, but the intermediate values were numerically exact), except those in specifications.

Define

$$F = 0.38848145378003529$$
$$R = 29.482183021342301$$
$$z = 1.3173270022537199$$

$$\mathcal{M}_{16} \equiv \begin{pmatrix} 0.401288 & 0.650173 & -0.051461 \\ -0.250268 & 1.204414 & 0.045854 \\ -0.002079 & 0.048952 & 0.953127 \end{pmatrix}$$

$$\boldsymbol{\mathcal{D}} \equiv \begin{pmatrix} 1.0211774459482703 \\ 0.98630789117685210 \\ 0.93396137406301061 \end{pmatrix}$$

$$\mathcal{S} \equiv \begin{pmatrix} 2 & 1 & \frac{1}{20} \\ 1 & -\frac{12}{11} & \frac{1}{11} \\ \frac{1}{9} & \frac{1}{9} & -\frac{2}{9} \end{pmatrix}$$

$$f(s) \equiv 400 \operatorname{sign}(s) \frac{(0.01sF)^{0.42}}{(0.01sF)^{0.42} + 27.13}$$

$$f^{-1}(s) \equiv \frac{100}{F} \operatorname{sign}(s) \left(\frac{27.13|s|}{400 - |s|}\right)^{\frac{1}{0.42}}$$

$$\begin{aligned} \mathrm{e}(h) \equiv 1 &- 0.0582 \cos h - 0.0258 \cos 2h \\ &- 0.1347 \cos 3h + 0.0289 \cos 4h \\ &- 0.1475 \sin h - 0.0308 \sin 2h \\ &+ 0.0385 \sin 3h + 0.0096 \sin 4h \end{aligned}$$

From CIE XYZ to CAM16

Input: CIE XYZ vector $\boldsymbol{X}$

Output: CAM16 (JCh) vector $\begin{pmatrix} J & C & h \end{pmatrix}^{\mathrm{T}}$

$$\boldsymbol{M} = \mathcal{M}_{16}\boldsymbol{X}$$

$$\begin{pmatrix} A \\ a \\ b \end{pmatrix} = \mathcal{S} \begin{pmatrix} f(\boldsymbol{\mathcal{D}}_1\boldsymbol{M}_1) \\ f(\boldsymbol{\mathcal{D}}_2\boldsymbol{M}_2) \\ f(\boldsymbol{\mathcal{D}}_3\boldsymbol{M}_3) \end{pmatrix}$$

Hue angle (in degrees)

$$h = \frac{180^\circ}{\pi} \arctan \frac{b}{a}$$

Chroma (proposed)

$$C = \frac{1505}{R} \mathrm{e}\left(\frac{\pi}{180^\circ} h\right) \sqrt{a^2 + b^2}$$

Lightness

$$J = 100 \left(\frac{A}{R}\right)^z$$

From CAM16 to CIE XYZ

Input: CAM16 (JCh) vector $\begin{pmatrix} J & C & h \end{pmatrix}^{\mathrm{T}}$

Output: CIE XYZ vector $\boldsymbol{X}$

$$A = R \left(\frac{J}{100}\right)^{\frac{1}{z}}$$

$$h' = \frac{\pi}{180^\circ} h$$

$$\begin{pmatrix} a \\ b \end{pmatrix} = \frac{R}{1505} \mathrm{e}(h') \begin{pmatrix} \cos h' \\ \sin h' \end{pmatrix}$$

$$\boldsymbol{M}' = \mathcal{S}^{-1} \begin{pmatrix} A \\ a \\ b \end{pmatrix}$$

$$\boldsymbol{X} = \mathcal{M}_{16}^{-1} \begin{pmatrix} \frac{f^{-1}(\boldsymbol{M}'_1)}{\boldsymbol{\mathcal{D}}_1} \\ \frac{f^{-1}(\boldsymbol{M}'_2)}{\boldsymbol{\mathcal{D}}_2} \\ \frac{f^{-1}(\boldsymbol{M}'_3)}{\boldsymbol{\mathcal{D}}_3} \end{pmatrix}$$

Appendix

$$\mathcal{M}_{16}^{-1} \equiv \begin{pmatrix} 1.8620678550872327 & -1.0112546305316844 & 0.14918677544445172 \\ 0.38752654323613716 & 0.62144744193147536 & -0.0089739851676125183 \\ -0.015841498849333855 & -0.034122938028515564 & 1.0499644368778494 \end{pmatrix}$$

The below reference white $\boldsymbol{w}_{\mathrm{D65}}$ was used in the overall calculation.

$$\boldsymbol{w}_{\mathrm{D65}} \equiv \begin{pmatrix} 95.047055865428191 \\ 100 \\ 108.88287363958874 \end{pmatrix}$$

Conversions between CIE XYZ and sRGB

$$\mathcal{M} \equiv 100 \begin{pmatrix} 0.41245744558236514 & 0.35757586524551642 & 0.18043724782640035 \\ 0.21267337037840703 & 0.71515173049103283 & 0.072174899130560142 \\ 0.019333942761673366 & 0.11919195508183881 & 0.95030283855237520 \end{pmatrix}$$

$$\mathcal{M}^{-1} \equiv \frac{1}{100} \begin{pmatrix} 3.2404462546477561 & -1.5371347618200895 & 0.49853019302273171 \\ -0.96926660624467829 & 1.8760119597883673 & 0.041556042214430008 \\ 0.055643503564352598 & -0.20402617973595953 & 1.0572265677226994 \end{pmatrix}$$

$$f(c) \equiv \begin{cases} \left(\dfrac{c + 0.055}{1.055}\right)^{2.4}, & c \geq 3.530633592050228\mathrm{E}-5 \\ \dfrac{c}{0.010775438668478016}, & otherwise \end{cases}$$

$$f^{-1}(c) \equiv \begin{cases} 1.055c^{\frac{1}{2.4}} - 0.055, & c \geq 0.003039934639778422 \\ 0.010775438668478016\mathrm{c}, & otherwise \end{cases}$$

From sRGB to CIE XYZ

Input: sRGB vector $(R \quad G \quad B)^{\mathrm{T}}$
Output: CIE XYZ vector $\boldsymbol{X}$

$$\boldsymbol{X} = \mathcal{M} \begin{pmatrix} f(R) \\ f(G) \\ f(B) \end{pmatrix}$$

From CIE XYZ to sRGB

Input: CIE XYZ vector $\boldsymbol{X}$
Output: sRGB vector $\boldsymbol{R}$

$$\boldsymbol{L} = \mathcal{M}^{-1}\boldsymbol{X}$$

$$\boldsymbol{R} = \begin{pmatrix} f^{-1}(\boldsymbol{L}_1) \\ f^{-1}(\boldsymbol{L}_2) \\ f^{-1}(\boldsymbol{L}_3) \end{pmatrix}$$