

Full-vector gradient : une approche plus complète du gradient couleur.

Hermine Chatoux, Noël Richard,
François Lecellier, Christine Fernandez-Maloigne

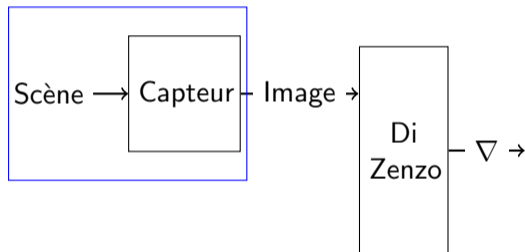
Xlim
Université de Poitiers
Pour le GdR ISIS

21 novembre 2018

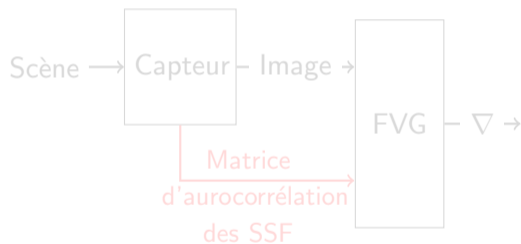


Deux approches du gradient couleur

- Toises, pieds, coudées



(a) Approches précédentes

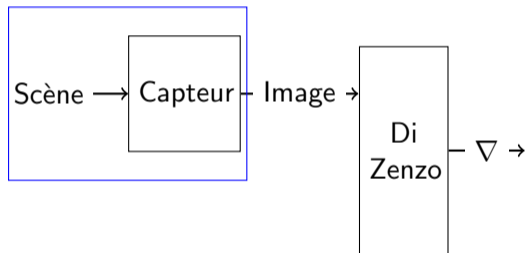


(b) Approche proposée

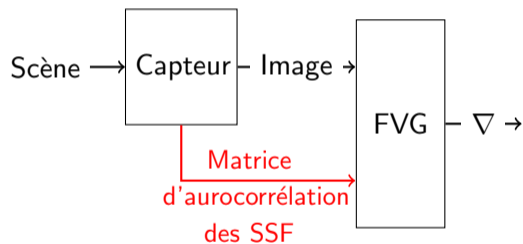
Plusieurs méthodes de mesure → quantité liée uniquement à l'objet à mesurer.

Deux approches du gradient couleur

- Toises, pieds, coudées \rightarrow mètres.



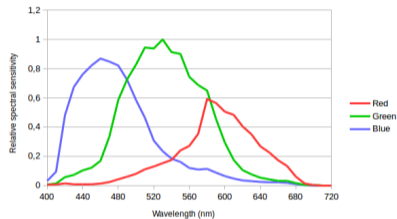
(a) Approches précédentes



(b) Approche proposée

Plusieurs méthodes de mesure \rightarrow quantité liée uniquement à l'objet à mesurer.

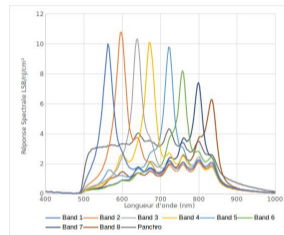
Problématique



(a) SSF couleur



(b) Photo



(c) SSF multi-spectral

Dépendance aux capteurs

Comment rendre le calcul du gradient indépendant de l'appareil d'acquisition ?

Sommaire

- 1 Méthodes
 - Di Zeno gradient
 - Full-vector gradient
- 2 Vers le domaine physique,
 - Protocole
 - Résultats
- 3 Et au delà !
 - Protocole
 - Résultats
- 4 Conclusion

Content

- 1 Méthodes
 - Di Zeno gradient
 - Full-vector gradient
- 2 Vers le domaine physique,
 - Protocole
 - Résultats
- 3 Et au delà !
 - Protocole
 - Résultats
- 4 Conclusion

Di Zenzo gradient [1]

- Gradient estimé par la matrice de corrélation spatiale :

$$ACor = \begin{pmatrix} \left\| \frac{\partial I(x,c)}{\partial x_1} \right\|_2^2 & \left\langle \frac{\partial I(x,c)}{\partial x_1}, \frac{\partial I(x,c)}{\partial x_2} \right\rangle \\ \left\langle \frac{\partial I(x,c)}{\partial x_1}, \frac{\partial I(x,c)}{\partial x_2} \right\rangle & \left\| \frac{\partial I(x,c)}{\partial x_2} \right\|_2^2 \end{pmatrix}.$$

- Produit scalaire utilisé par Di Zenzo:

$$\left\langle \frac{\partial I(x,c)}{\partial x_i}, \frac{\partial I(x,c)}{\partial x_j} \right\rangle = \sum_{k=1}^n \left\langle \frac{\partial I(x, c_k)}{\partial x_i}, \frac{\partial I(x, c_k)}{\partial x_j} \right\rangle$$

- Produit scalaire complet pour l'intégration de l'information couleur :

$$\left\langle \frac{\partial I(x,c)}{\partial x_i}, \frac{\partial I(x,c)}{\partial x_j} \right\rangle = \sum_{k=1}^n \sum_{l=1}^n \left\langle \frac{\partial I(x, c_k)}{\partial x_i}, \frac{\partial I(x, c_l)}{\partial x_j} \right\rangle.$$

Di Zenzo gradient [1]

- Gradient estimé par la matrice de corrélation spatiale :

$$ACor = \begin{pmatrix} \left\| \frac{\partial I(x,c)}{\partial x_1} \right\|_2^2 & \left\langle \frac{\partial I(x,c)}{\partial x_1}, \frac{\partial I(x,c)}{\partial x_2} \right\rangle \\ \left\langle \frac{\partial I(x,c)}{\partial x_1}, \frac{\partial I(x,c)}{\partial x_2} \right\rangle & \left\| \frac{\partial I(x,c)}{\partial x_2} \right\|_2^2 \end{pmatrix}.$$

- Produit scalaire utilisé par Di Zenzo:

$$\left\langle \frac{\partial I(x,c)}{\partial x_i}, \frac{\partial I(x,c)}{\partial x_j} \right\rangle = \sum_{k=1}^n \left\langle \frac{\partial I(x, c_k)}{\partial x_i}, \frac{\partial I(x, c_k)}{\partial x_j} \right\rangle$$

- Produit scalaire complet pour l'intégration de l'information couleur :

$$\left\langle \frac{\partial I(x,c)}{\partial x_i}, \frac{\partial I(x,c)}{\partial x_j} \right\rangle = \sum_{k=1}^n \sum_{l=1}^n \left\langle \frac{\partial I(x, c_k)}{\partial x_i}, \frac{\partial I(x, c_l)}{\partial x_j} \right\rangle.$$

Full-vector gradient [2]

- Produit scalaire pour une base non orthogonale :

$$\langle c_i, c_j \rangle = c_i^T \cdot Gm \cdot c_j,$$

avec la matrice de Gram :

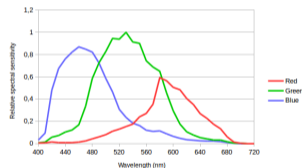
$$Gm = \begin{pmatrix} \|s_0\|_2^2 & \langle s_0, s_1 \rangle & \dots & \langle s_0, s_m \rangle \\ \langle s_1, s_0 \rangle & \|s_1\|_2^2 & \dots & \langle s_1, s_m \rangle \\ \vdots & \vdots & \ddots & \vdots \\ \langle s_m, s_0 \rangle & \dots & \langle s_m, s_{m-1} \rangle & \|s_m\|_2^2 \end{pmatrix},$$

Le produit scalaire de la matrice de Gram est habituellement défini dans une base orthogonale de l'espace.

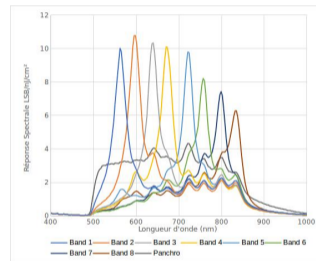
Full Vector Gradient

- Pas de base orthogonale connue.
- Produit scalaire des fonctions intégrables :

$$\langle s_i, s_j \rangle = \int_{\mathbb{R}} S_i(\lambda) S_j(\lambda) d\lambda.$$



(a) Capteur couleur



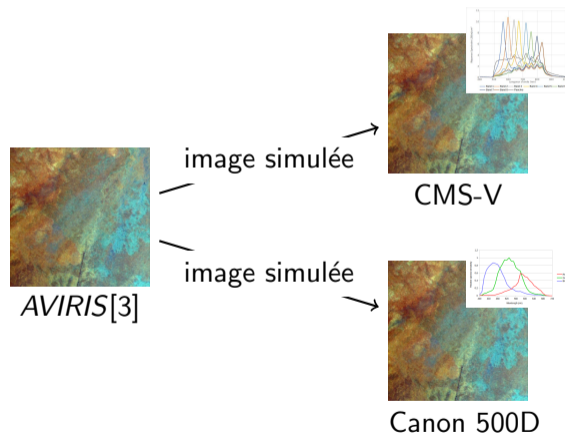
(b) Capteur multi-spectral

- Spectral Sensitivity Functions (SSF) :
mesure $\Rightarrow S_i(\lambda) \geq 0$.

Content

- 1 Méthodes
 - Di Zenzo gradient
 - Full-vector gradient
- 2 Vers le domaine physique,
 - Protocole
 - Résultats
- 3 Et au delà !
 - Protocole
 - Résultats
- 4 Conclusion

Méthode de calcul



$$C_i = \int_{\lambda_{min}}^{\lambda_{max}} S_i(\lambda) I_h(\lambda) d\lambda,$$

avec

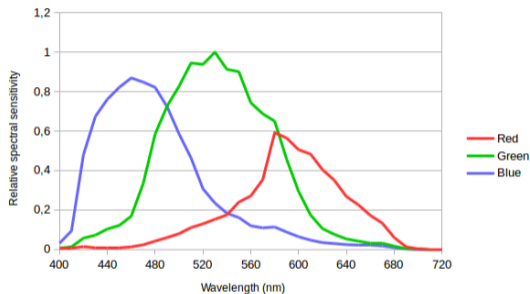
$$I_h(\lambda) = R(\lambda) III(\lambda).$$

Capteur couleur

- Canon 500D 3 canaux :
 - rouge, vert et bleu.

$$\begin{pmatrix} 20 & 23 & 7 \\ 23 & 80 & 38 \\ 7 & 38 & 55 \end{pmatrix}$$

Matrice de Gram



SSF

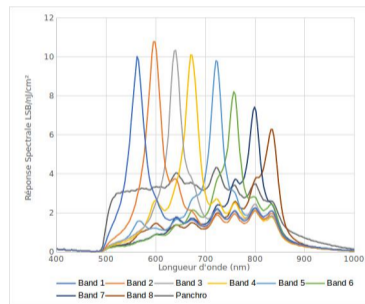
Sensibilité du rouge plus faible que les autres canaux \Rightarrow coefficient plus faible.

Capteur multi-spectral

- CMS-V SILIOS Technologies 9 canaux :
 - 8 filtres sélectifs centrés en : 561, 596, 638, 673, 722, 758, 801 et 838 nm,
 - 1 filtre panchromatique.

3615	2741	1856	1831	1857	1489	1452	1475	2933
2741	4293	2751	2435	1879	1585	1570	1638	3131
1856	2751	3813	2939	2030	1783	1792	1617	3045
1831	2435	2939	3803	2393	2015	1827	1641	3023
1857	1879	2030	2393	3326	2356	1904	1662	2859
1489	1585	1783	2015	2356	2662	2070	1738	2427
1452	1570	1792	1827	1904	2070	2326	1837	2287
1475	1638	1617	1641	1662	1738	1837	1973	2101
2933	3131	3045	3023	2859	2427	2287	2101	3785

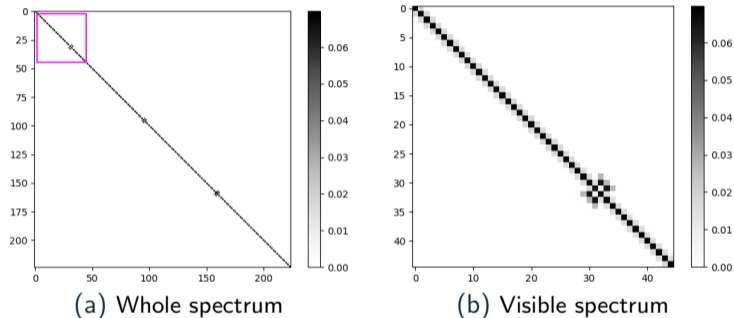
Matrice de Gram



SSF

Capteur hyper-spectral

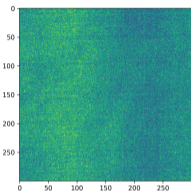
- AVIRIS constitué de 3 capteurs :
 - visible (366 à 668 nm),
 - proche infrarouge (656 à 1263 nm),
 - infrarouge (1253 à 2496 nm).



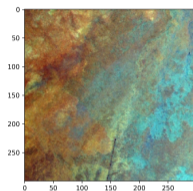
Matrice de Gram

Matrice presque diagonale \Rightarrow matrice bande.

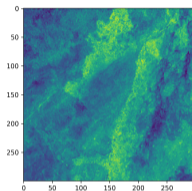
Restreint au visible [360, 780] nm



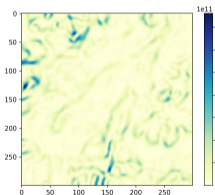
(a) canal 366 nm



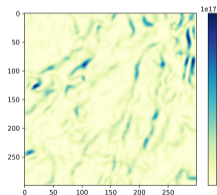
(b) Initial image



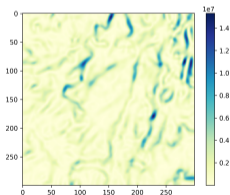
(c) canal 773 nm



(d) Couleur



(e) Multi-spectral

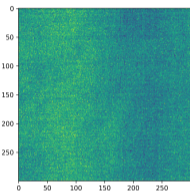


(f) Hyper-spectral

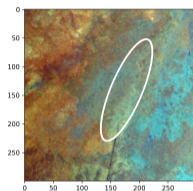
Observations

- Dynamiques différentes.
- Apport de la sélectivité des canaux.

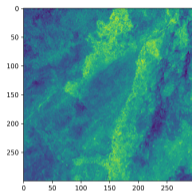
Restreint au visible [360, 780] nm



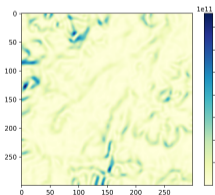
(a) canal 366 nm



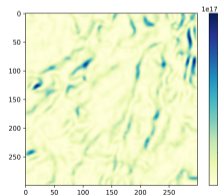
(b) Initial image



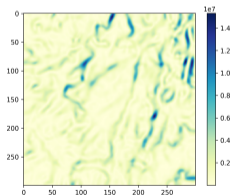
(c) canal 773 nm



(d) Couleur



(e) Multi-spectral

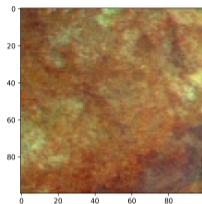


(f) Hyper-spectral

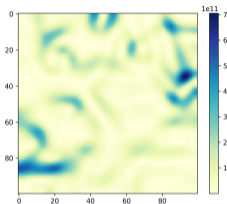
Observations

- Dynamiques différentes.
- Apport de la sélectivité des canaux.

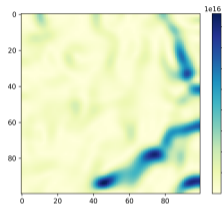
Restreint au visible [360, 780]nm



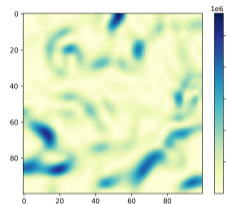
(a) Zoom



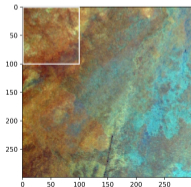
(b) Couleur



(c) Multi-spectral



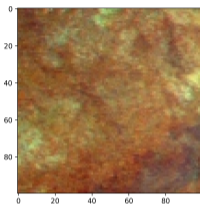
(d) Hyper-spectral



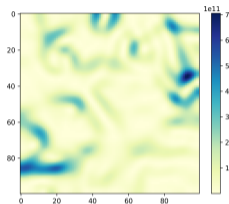
Observations

- Plus de détails avec une échelle ajustée.
- Pas de canal bleu pour le capteur multi-spectral.

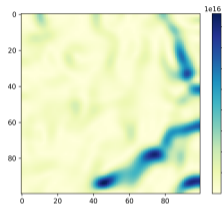
Restreint au visible [360, 780]nm



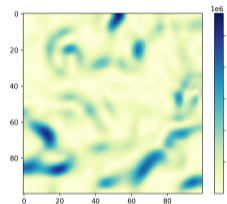
(a) Zoom



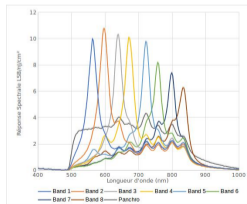
(b) Couleur



(c) Multi-spectral



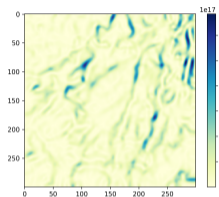
(d) Hyper-spectral



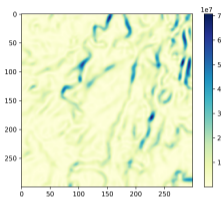
Observations

- Plus de détails avec une échelle ajustée.
- Pas de canal bleu pour le capteur multi-spectral.

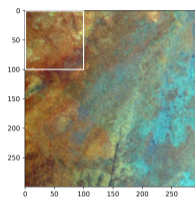
Totalité du capteur



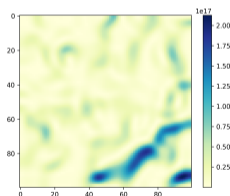
(a) Multi-spectral



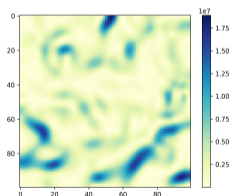
(b) Hyper-spectral



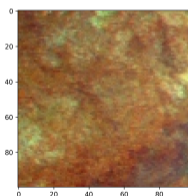
(c) Image initiale



(d) Multi-spectral



(e) Hyper-spectral

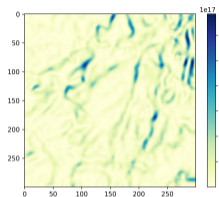


(f) Zoom

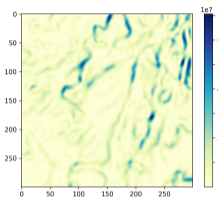
Observations

- Résultats similaires,
- importance de la sélectivité des canaux dans l'infrarouge ?

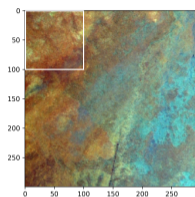
Totalité du capteur



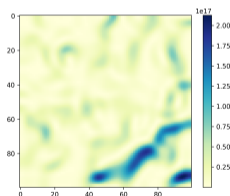
(a) Multi-spectral



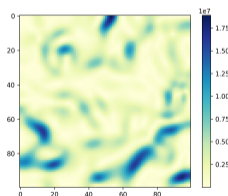
(b) Hyper-spectral



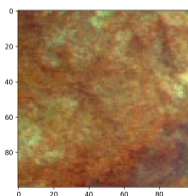
(c) Image initiale



(d) Multi-spectral



(e) Hyper-spectral



(f) Zoom

Observations

- Résultats similaires,
- importance de la sélectivité des canaux dans l'infrarouge ?

Content

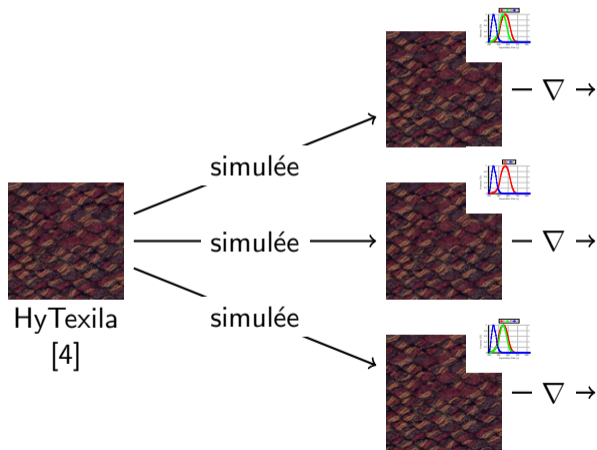
- 1 Méthodes
 - Di Zenzo gradient
 - Full-vector gradient
- 2 Vers le domaine physique,
 - Protocole
 - Résultats
- 3 Et au delà !
 - Protocole
 - Résultats
- 4 Conclusion

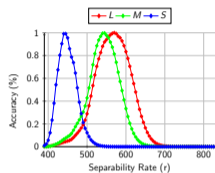
Quid du SVH ?

Question ouverte

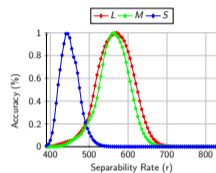
Impact de l'inter-corrélation
des cônes
dans la vision humaine ?

- Espace *LMS* :
 - au niveau de l'œil,
 - calcul direct sans adaptation,
 - définition simple des CVD.

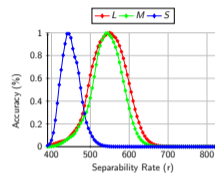


Daltonisme et *LMS*

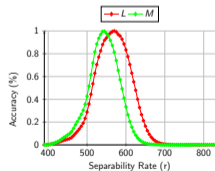
(a) Vision normale



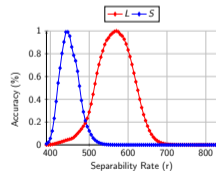
(b) Deuteranomalie



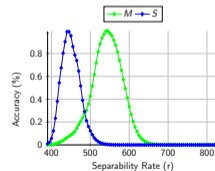
(c) Protanomalie



(d) Tritanope



(e) Deuteranope



(f) Protanope

Shrestha [5]

- Décalage des CMF pour les anomalies,
- suppression des cônes pour les dichromates.

Matrice de Gram

	Normal	Cône anormal	Cône manquant
L		$\begin{pmatrix} \mathbf{85.487} & 74.211 & 8.392 \\ 74.211 & \mathbf{66.054} & 6.876 \\ 8.392 & 6.876 & \mathbf{41.166} \end{pmatrix}$	$\begin{pmatrix} \mathbf{66.054} & 6.876 \\ 6.876 & \mathbf{41.166} \end{pmatrix}$
M	$\begin{pmatrix} \mathbf{85.487} & 68.859 & 4.305 \\ 68.859 & \mathbf{66.054} & 6.876 \\ 4.305 & 6.876 & \mathbf{41.166} \end{pmatrix}$	$\begin{pmatrix} \mathbf{85.487} & 74.211 & 4.305 \\ 74.211 & \mathbf{66.054} & 3.320 \\ 4.305 & 3.320 & \mathbf{41.166} \end{pmatrix}$	$\begin{pmatrix} \mathbf{85.487} & 4.305 \\ 4.305 & \mathbf{41.166} \end{pmatrix}$
S			$\begin{pmatrix} \mathbf{85.487} & 68.859 \\ 68.859 & \mathbf{66.054} \end{pmatrix}$

Matrice de Gram

	Normal	Cône anormal	Cône manquant
L	$\begin{pmatrix} 85.487 & 68.859 & 4.305 \\ 68.859 & 66.054 & 6.876 \\ 4.305 & 6.876 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 85.487 & 74.211 & 8.392 \\ 74.211 & 66.054 & 6.876 \\ 8.392 & 6.876 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 66.054 & 6.876 \\ 6.876 & 41.166 \end{pmatrix}$
M		$\begin{pmatrix} 85.487 & 74.211 & 4.305 \\ 74.211 & 66.054 & 3.320 \\ 4.305 & 3.320 & 41.166 \end{pmatrix}$	$\begin{pmatrix} \mathbf{85.487} & 4.305 \\ 4.305 & \mathbf{41.166} \end{pmatrix}$
S			$\begin{pmatrix} 85.487 & 68.859 \\ 68.859 & 66.054 \end{pmatrix}$

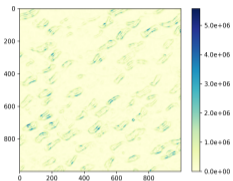
Matrice de Gram

	Normal	Cône anormal	Cône manquant
L		$\begin{pmatrix} 85.487 & \mathbf{74.211} & 8.392 \\ 74.211 & 66.054 & 6.876 \\ 8.392 & 6.876 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 66.054 & 6.876 \\ 6.876 & 41.166 \end{pmatrix}$
M	$\begin{pmatrix} 85.487 & 68.859 & 4.305 \\ 68.859 & 66.054 & 6.876 \\ 4.305 & 6.876 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 85.487 & \mathbf{74.211} & 4.305 \\ 74.211 & 66.054 & 3.320 \\ 4.305 & 3.320 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 85.487 & 4.305 \\ 4.305 & 41.166 \end{pmatrix}$
S			$\begin{pmatrix} 85.487 & 68.859 \\ 68.859 & 66.054 \end{pmatrix}$

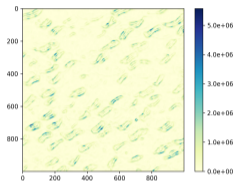
Matrice de Gram

	Normal	Cône anormal	Cône manquant
L		$\begin{pmatrix} 85.487 & 74.211 & 8.392 \\ 74.211 & 66.054 & 6.876 \\ 8.392 & 6.876 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 66.054 & 6.876 \\ 6.876 & 41.166 \end{pmatrix}$
M	$\begin{pmatrix} 85.487 & 68.859 & 4.305 \\ 68.859 & 66.054 & 6.876 \\ 4.305 & 6.876 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 85.487 & 74.211 & 4.305 \\ 74.211 & 66.054 & 3.320 \\ 4.305 & 3.320 & 41.166 \end{pmatrix}$	$\begin{pmatrix} 85.487 & 4.305 \\ 4.305 & 41.166 \end{pmatrix}$
S			$\begin{pmatrix} 85.487 & 68.859 \\ 68.859 & 66.054 \end{pmatrix}$

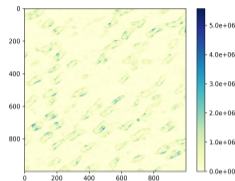
Dynamique fixe



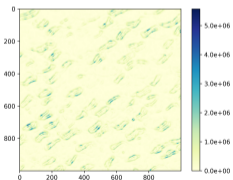
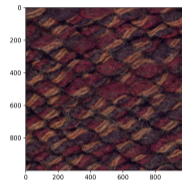
(a) Vision normale



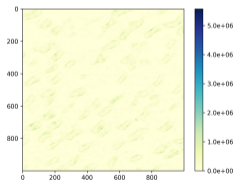
(b) Deuteramomalie



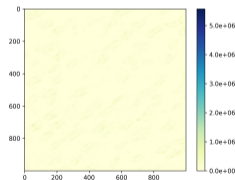
(c) Protanomalie



(d) Tritanope



(e) Deuteranope

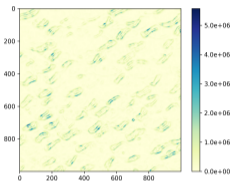


(f) Protanope

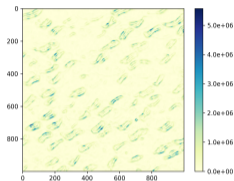
Observations

- Variations des dynamiques.
- Tritanope " > " dichromates.

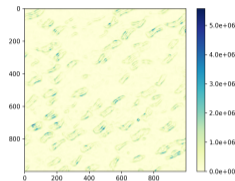
Dynamique fixe



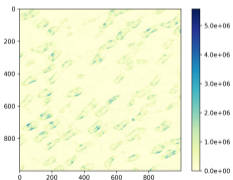
(a) Vision normale



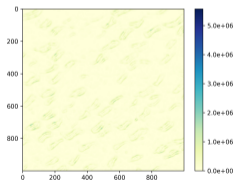
(b) Deuteranomalie



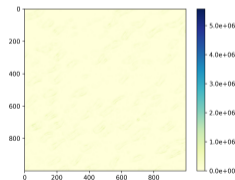
(c) Protanomalie



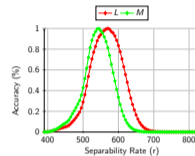
(d) Tritanope



(e) Deuteranope



(f) Protanope

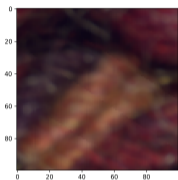


Tritanope

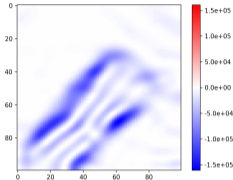
Observations

- Variations des dynamiques.
- Tritanope " > " dichromates.

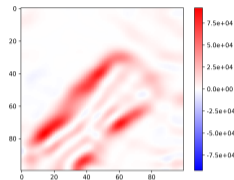
Différence à la vision normale



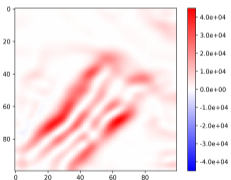
(a) Initial image



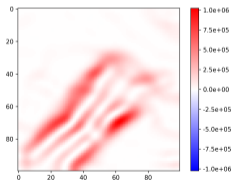
(b) Deuteranomalie



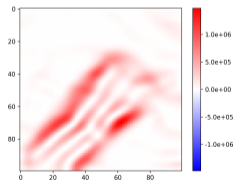
(c) Protanomalie



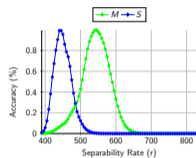
(d) Tritanope



(e) Deuteranope



(f) Protanope

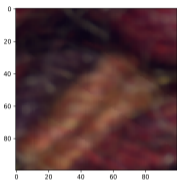


Protanope

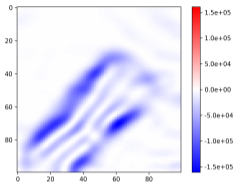
Observations

- Perte d'information.
- Amplitude la plus grande.
- Les plus grandes variations.

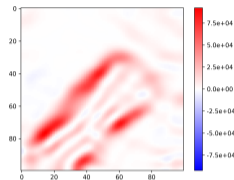
Différence à la vision normale



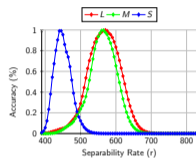
(a) Initial image



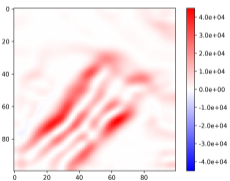
(b) Deuteranomalie



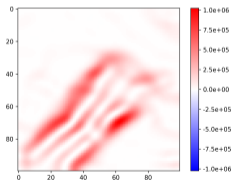
(c) Protanomalie



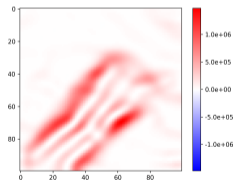
Deuteranomalie



(d) Tritanope



(e) Deuteranope

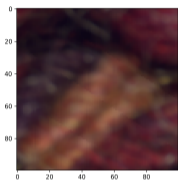


(f) Protanope

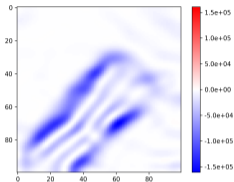
Observations

- Perte d'information.
- Amplitude la plus grande.
- Les plus grandes variations.

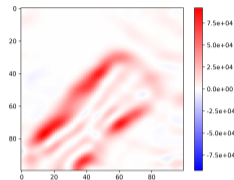
Différence à la vision normale



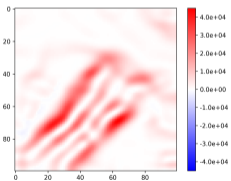
(a) Initial image



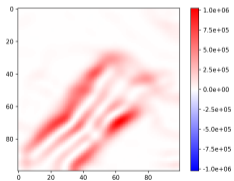
(b) Deuteranomalie



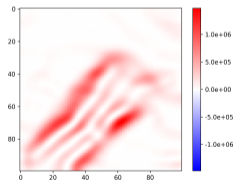
(c) Protanomalie



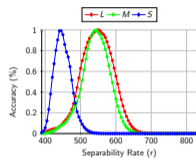
(d) Tritanope



(e) Deuteranope



(f) Protanope

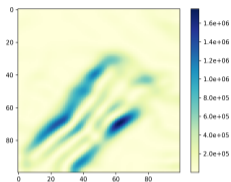


Protanomalie

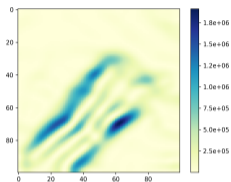
Observations

- Perte d'information.
- Amplitude la plus grande.
- Les plus grandes variations.

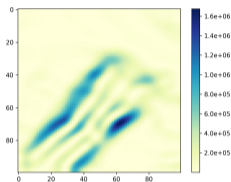
Dynamique variable



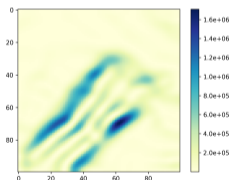
(a) Vision normale



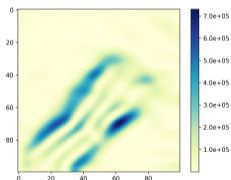
(b) Deuteramomalie



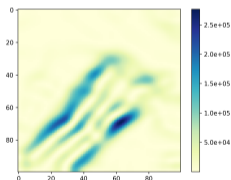
(c) Protanomalie



(d) Tritanope



(e) Deuteranope

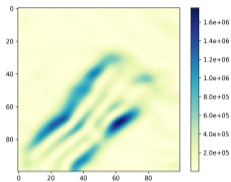


(f) Protanope

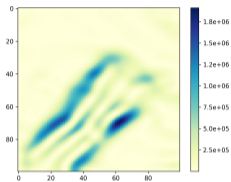
Observations

- Dynamiques différentes,
- mais contrastes similaires.

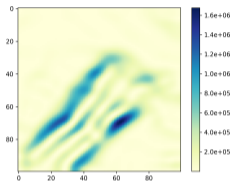
Dynamique variable



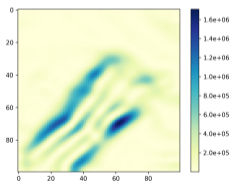
(a) Vision normale



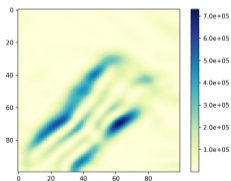
(b) Deuteranomalie



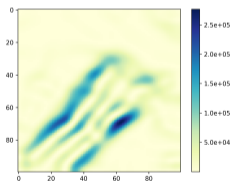
(c) Protanomalie



(d) Tritanope



(e) Deuteranope



(f) Protanope

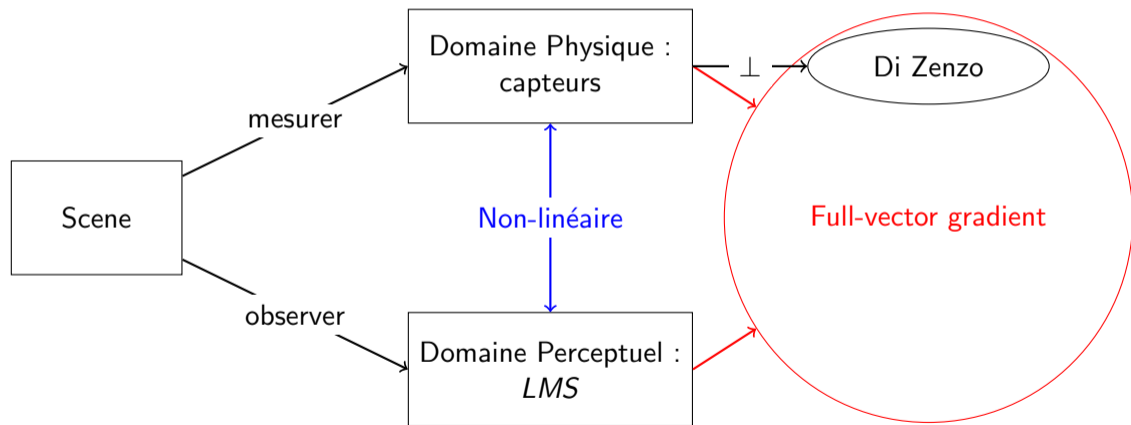
Observations

- Dynamiques différentes,
- mais contrastes similaires.

Content

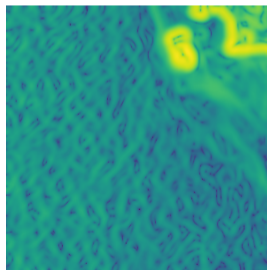
- 1 Méthodes
 - Di Zeno gradient
 - Full-vector gradient
- 2 Vers le domaine physique,
 - Protocole
 - Résultats
- 3 Et au delà !
 - Protocole
 - Résultats
- 4 Conclusion

Conclusion et perspectives







Merci de votre attention !


Avez vous des questions ?



Bibliographie I

-  S. Di Zeno, "A note on the gradient of a multi-image," *Computer vision, graphics, and image processing*, vol. 33, no. 1, pp. 116–125, 1986.
-  H. Chatoux, N. Richard, F. Lecellier, and C. Fernandez-Maloigne, "Full-vector gradient for multi-spectral or multivariate images," *IEEE Transactions on Image Processing*, 2018.
-  R. O. Green, M. L. Eastwood, C. M. Sarture, T. G. Chrien, M. Aronsson, B. J. Chippendale, J. A. Faust, B. E. Pavri, C. J. Chovit, M. Solis *et al.*, "Imaging spectroscopy and the airborne visible/infrared imaging spectrometer (aviris)," *Remote sensing of environment*, vol. 65, no. 3, pp. 227–248, 1998.
-  H. A. Khan, S. Mihoubi, B. Mathon, J.-B. Thomas, and J. Y. Hardeberg, "Hytexila: High resolution visible and near infrared hyperspectral texture images," *Sensors*, vol. 18, no. 7, p. 2045, 2018. [Online]. Available: <http://www.mdpi.com/1424-8220/18/7/2045>

Bibliographie II

-  R. Shrestha, “Simulating colour vision deficiency from a spectral image.” *Studies in health technology and informatics*, vol. 229, pp. 392–401, 2016.