
Color MRI

Nevit DİLMEN, MD

The Institute of Biomedical Engineering - Boğaziçi University
October 22, 2019 - 13:00

<http://bit.ly/NevitCMR>
nevitedilmen@sonomed.com.tr

Briefly

Why Color MRI?

- Speed up
- Ease of comprehension
- Ease of Education
- More...

What is Color MRI?

- Basic Physics & Physiology
- Brief History of Science

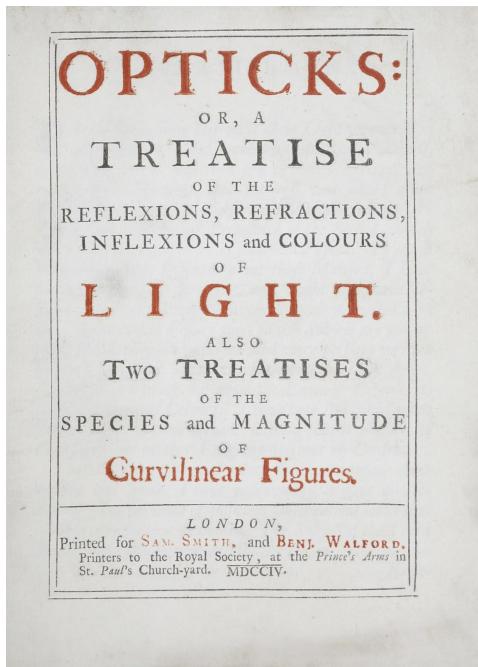
How?

- Creating Color MRI
- Understanding & Interpretation of Color MRI
- Samples

Who will benefit?

- Scientists
- Clinicians
- Radiologists

Isaac Newton, Opticks, 1704



James Clerk Maxwell, 1831-1879



Scottish physicist

- 1855 suggested that light is an electromagnetic wave.
- 1865 wrote formulas that combine electricity and magnetism.

Thomas Young, 1773-1829

British Physician and Physicist

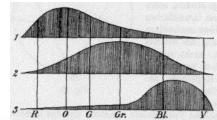
Young proposed that we don't need
endless sensors to see lots of colors.

Only three receptors red, green and
purple would suffice

This is the first **trichromatic** color theory.



Hermann von Helmholtz, 1821-1894



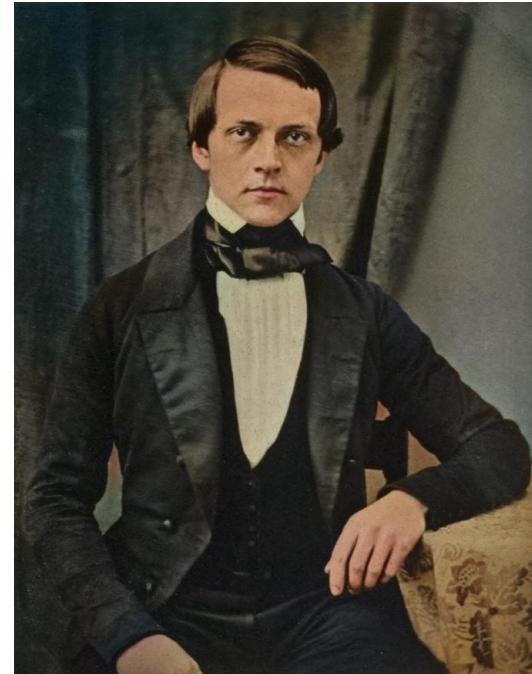
German physiologist and physicist

In 1802 he advanced the theory of vision proposed by Young.

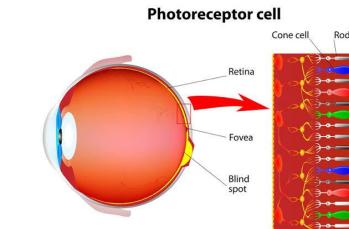
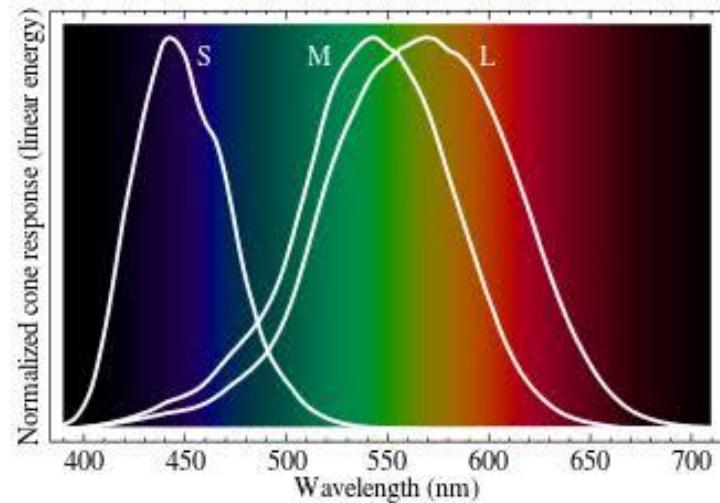
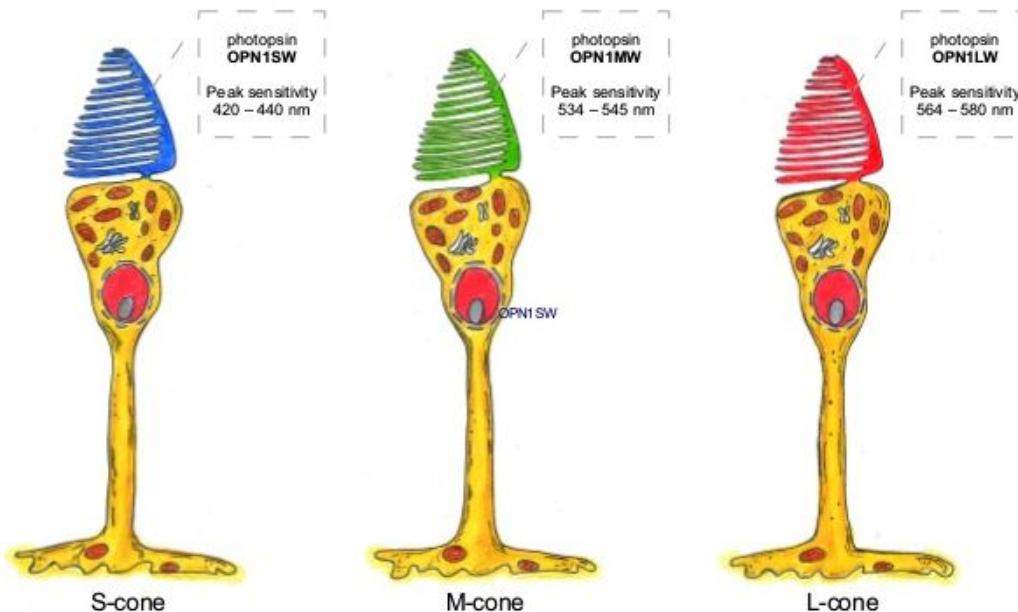
Three wavelengths proved to be sufficient for color vision.

In 1850, Helmholtz combined his three wavelength theory with Young's three receptor theory.

Young – Helmholtz Theory

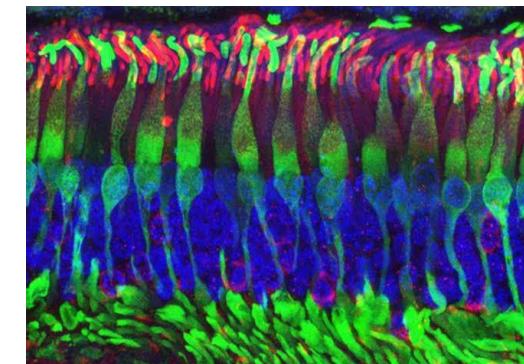
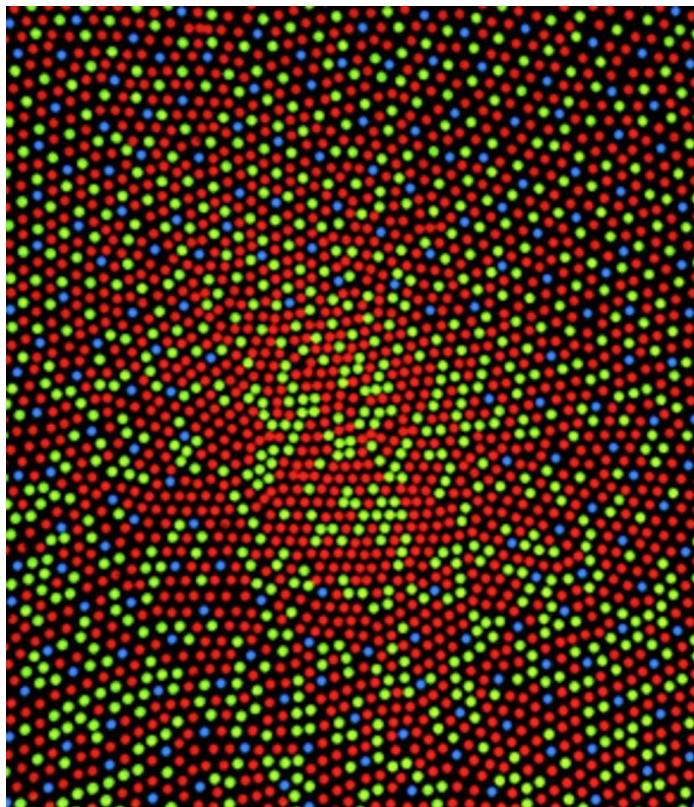


LMS: (Long, Medium, Short), RGB Cone Receptors



Young-Helmholtz: Receptors-Wavelengths

Cones in the retina



Tartan Ribbon, Maxwell, 1861

- Maxwell's three-color approach forms the basis of modern color images.
- The first durable color print, “Tartan Ribbon” was taken by Maxwell in 1861 based on method he proposed in 1855
- The actual print is in the National Media Museum in Bradford.



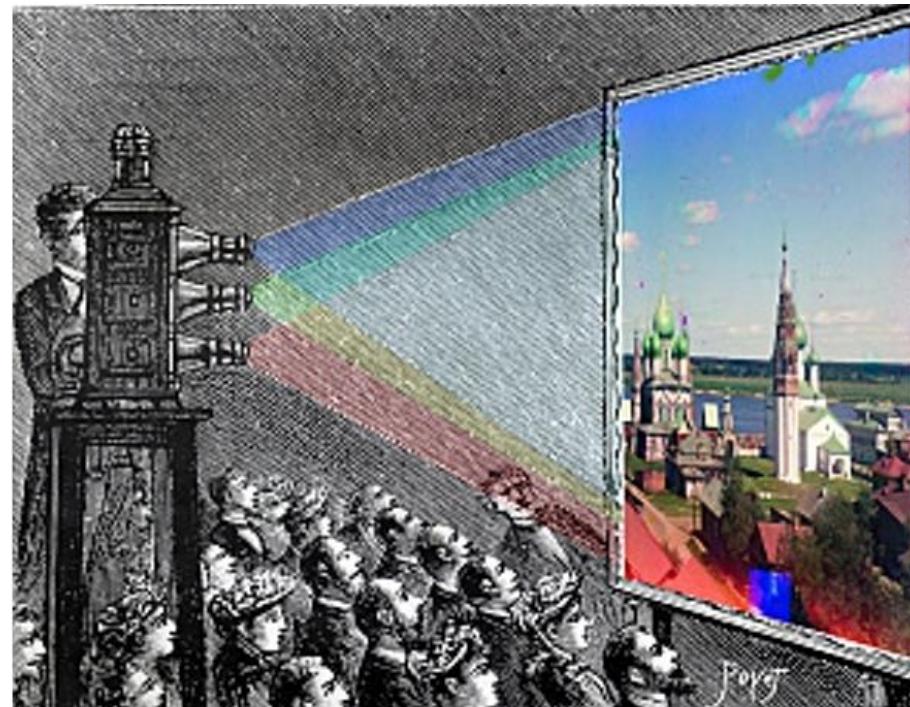
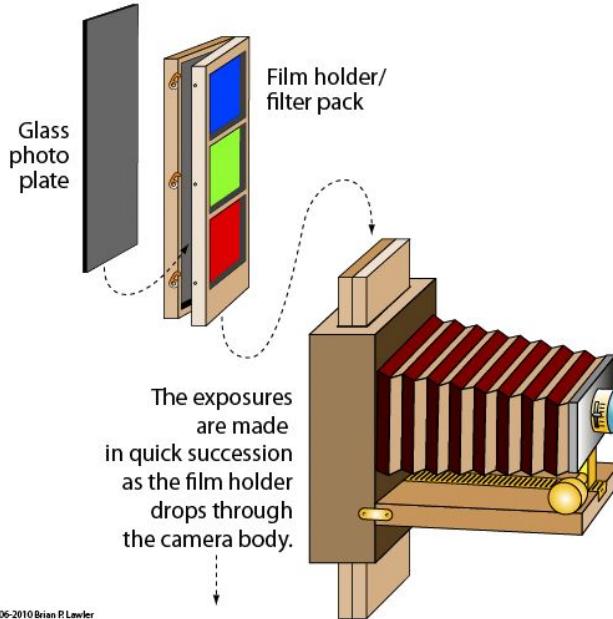
Sergei Mikhailovich Prokudin-Gorskiy, (1863-1944)

- Chemist and photographer.
- He color photographed the Russian Empire from 1909 to 1915 using Maxwell's method.
- His glass negatives were purchased in 1948 by the US Library of Congress.



Gorski's Camera and Projector

The Prokudin Gorskii Three-Color Camera



Emir Bukharskii (Emir of Bukhara), Gorski, 1910

Three black and white photos taken with **blue**, **green** and **red** filter.



Emir of Bukhara, 1910

After color
combination of
three plates.

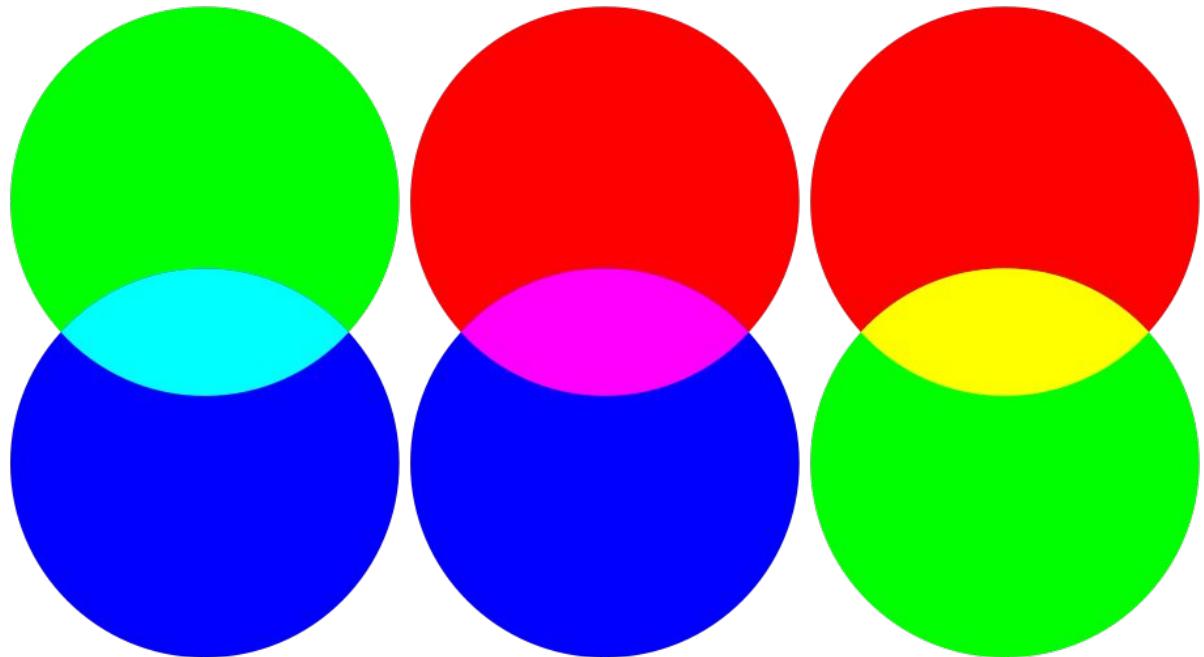
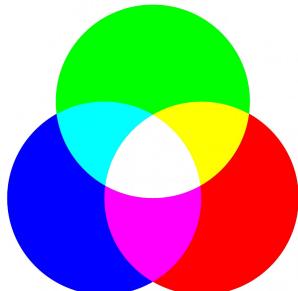
- Blue
- Green
- Red



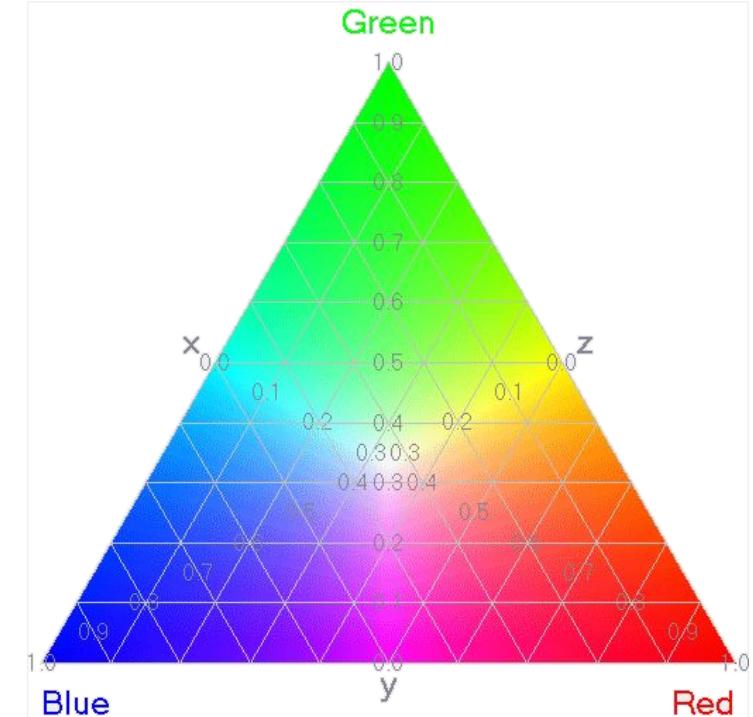
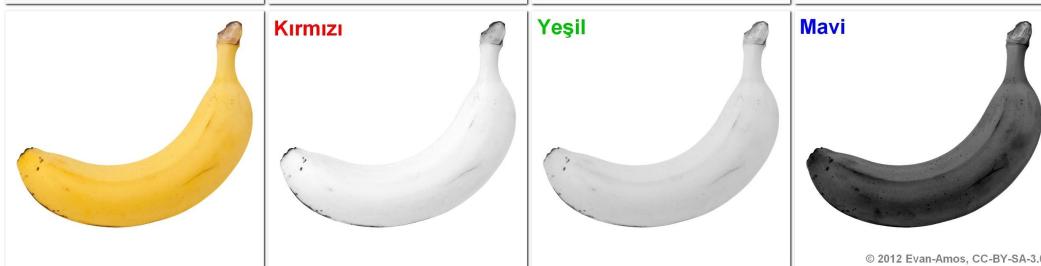
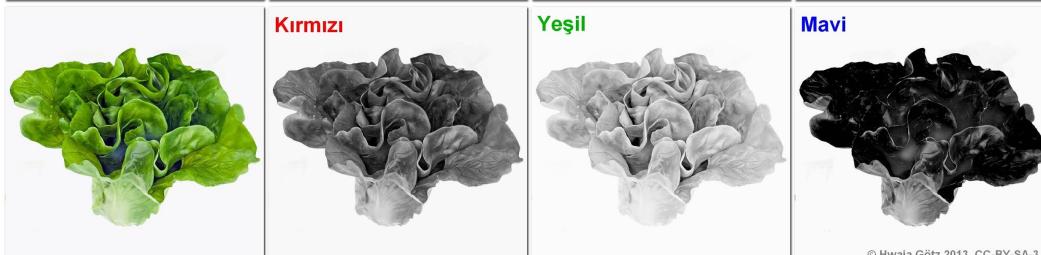
G + B = Cyan , R + B = Magenta , R + G = Yellow

Additive color combination applies to **light**.

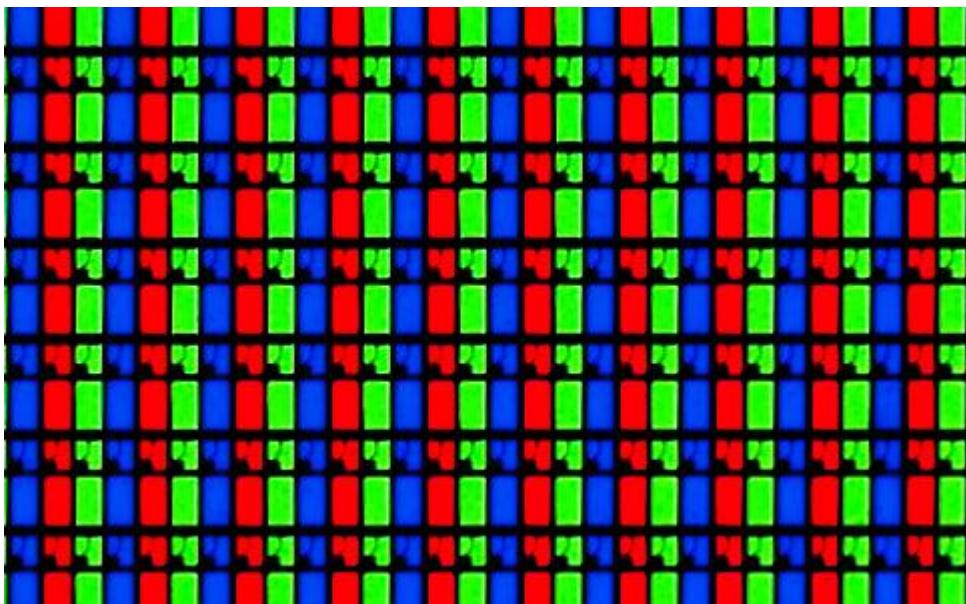
Subtractive combination applies to **paints**.



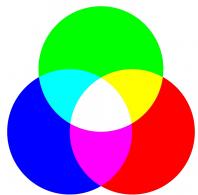
Maxwell's Triangle



RGB Pixels on the modern screen



Color MRI



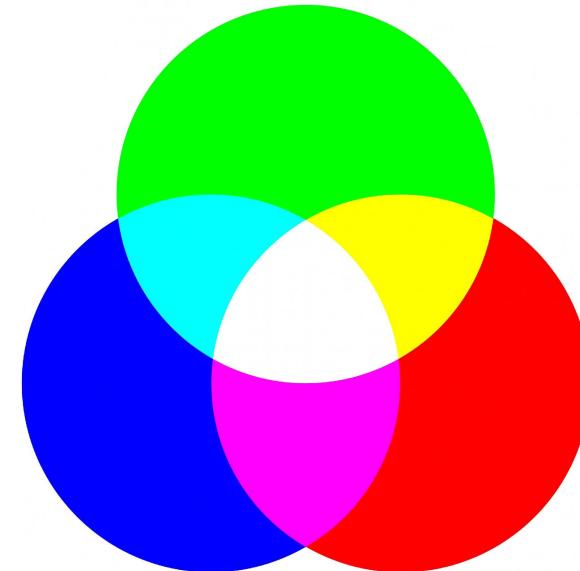
Trichromatic Color MRI,
is created by combining
three black and white images
into a **single** Color MR image.

Color MRI

T1W > Red

T2W > Green

Fat Sat T2 > Blue



T1 Weighted Image

In T1 Weighted image:

Fats are observed in light gray

Water is observed as dark gray



T2 Weighted Image

In T2 Weighted image:

Both Fats and Water are light colored



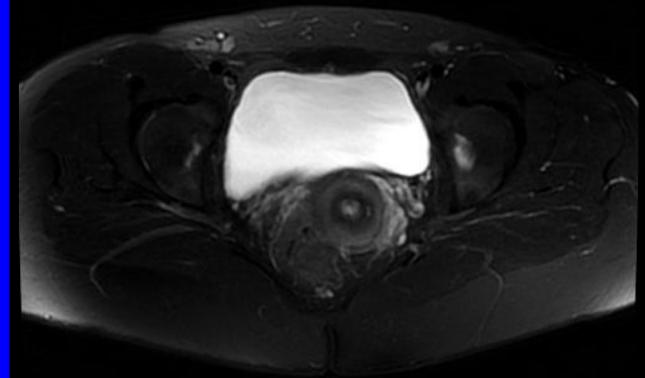
Fat-Sat T2 - STIR

In Fat-Sat T2 image:

Fats are dark and

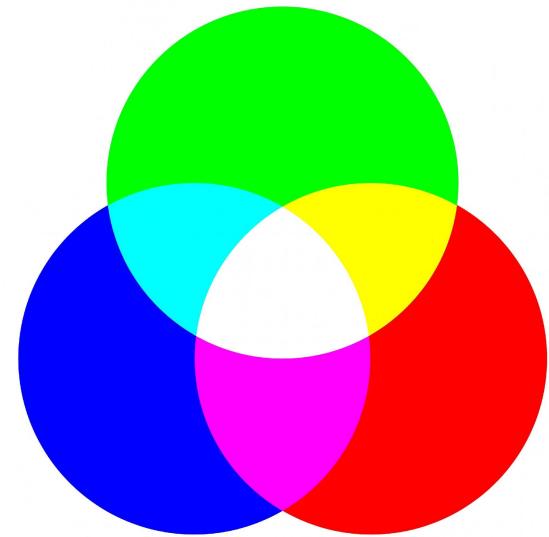
Water is light colored

YB-T2



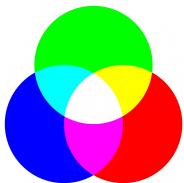
Color MRI

	Water	Fat
T1 Weighted	Dark	Light
T2 Weighted	Light	Light
Fat Sat T2	Light	Dark
Results:	Cyan	Yellow



Color MRI

	Myoglobin	Deoxyhemoglobin	Oxyhemoglobin
T1 Weighted	Mid Gray	Light	Light
T2 Weighted	Dark	Dark	Light
Fat Saturated T2	Dark	Dark	Light
Results:	Dark Red	Red	Gray



Color MR Claim (Hypothesis):

T1W, T2W ve Fat Sat-T2W

All information contained in three images
is presented in a single image.

**Color enhances Perception and Communication.
Speedup Workflow.**

Color MRI does not claim:

**It does not contain information from
sequences other than those included as
source images.**

Osirix Color MRI Plugin



<https://support.apple.com/downloads>

<https://www.osirix-viewer.com/>
<https://horosproject.org/>

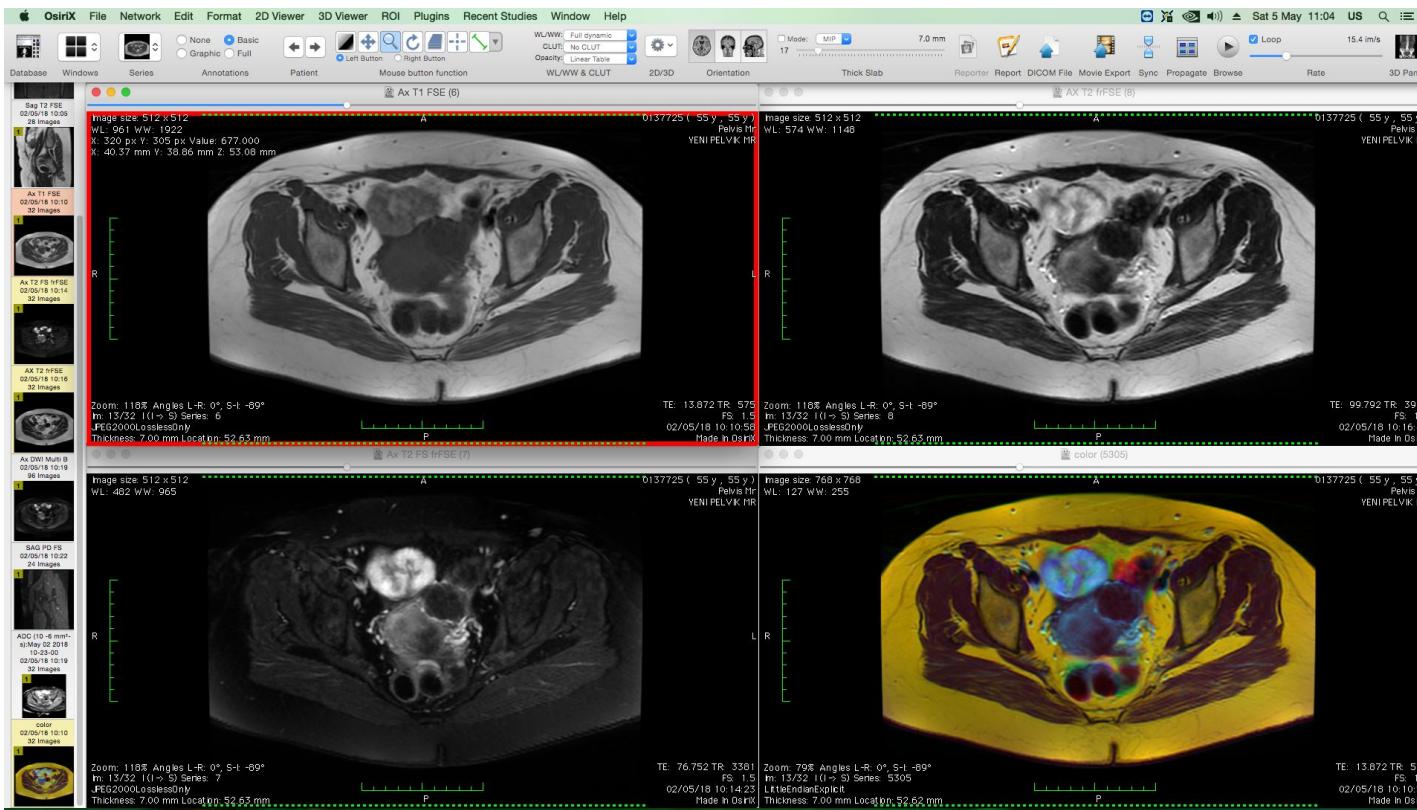
<http://bit.ly/OsirixColorMRI>

Osirix Color MRI Plugin

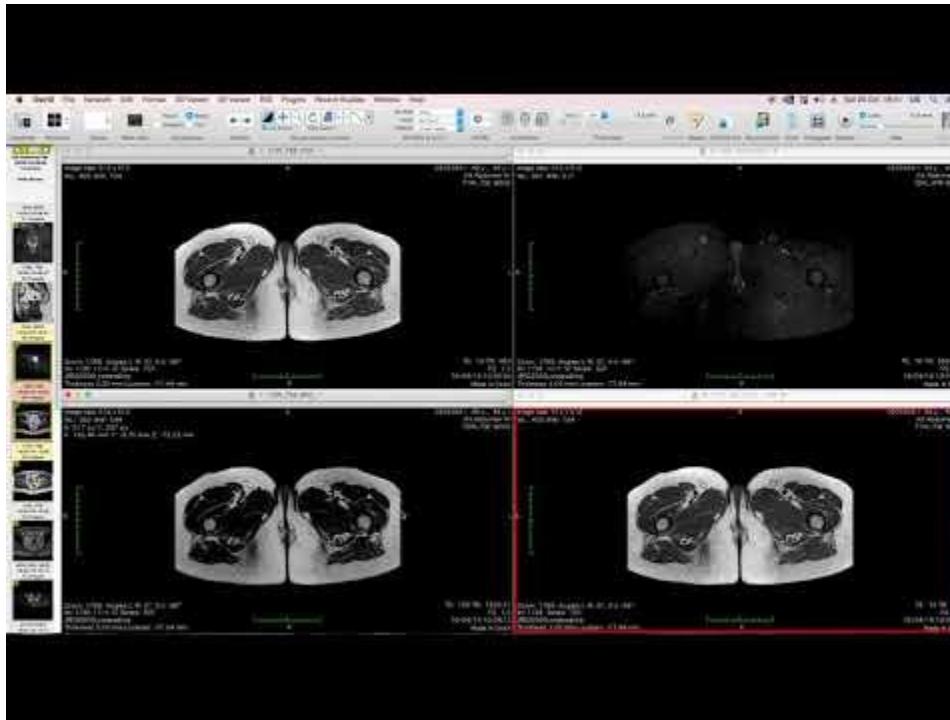
Does not require a new MRI hardware

It performs the combining process within
the Radiology workstation **software**.

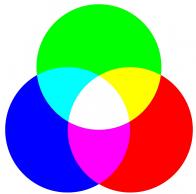
Osirix Workstation Screenshot



Osirix Color MRI Video (45s)



Sample Color MR Images



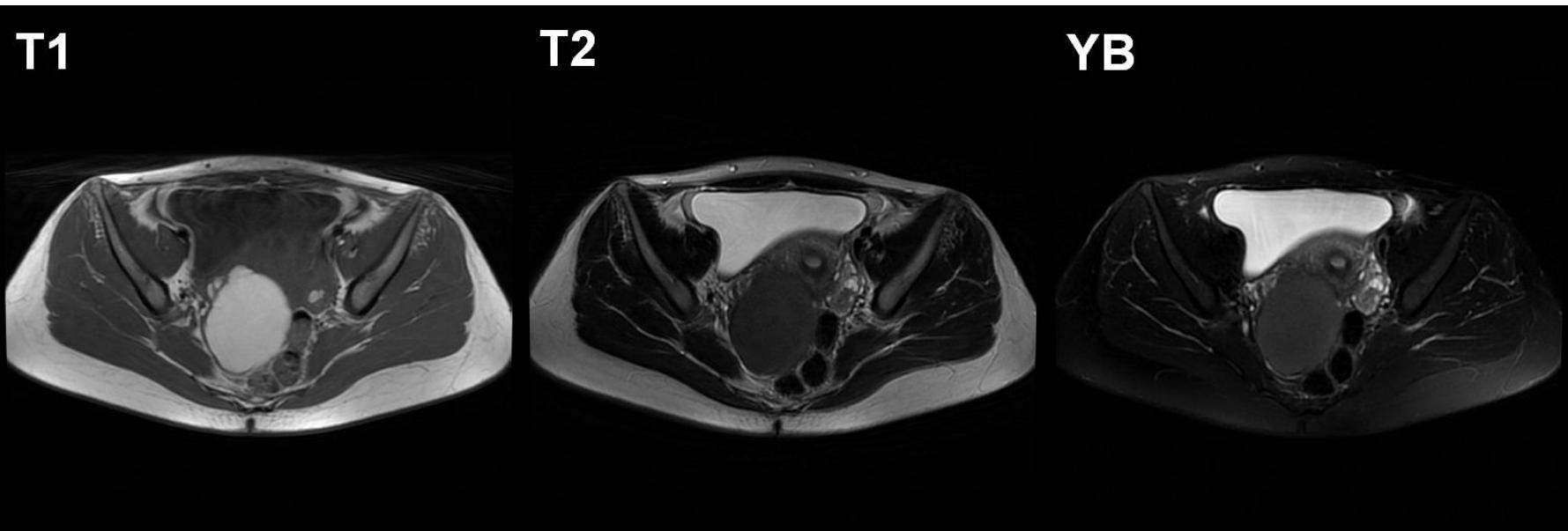
Lumbar



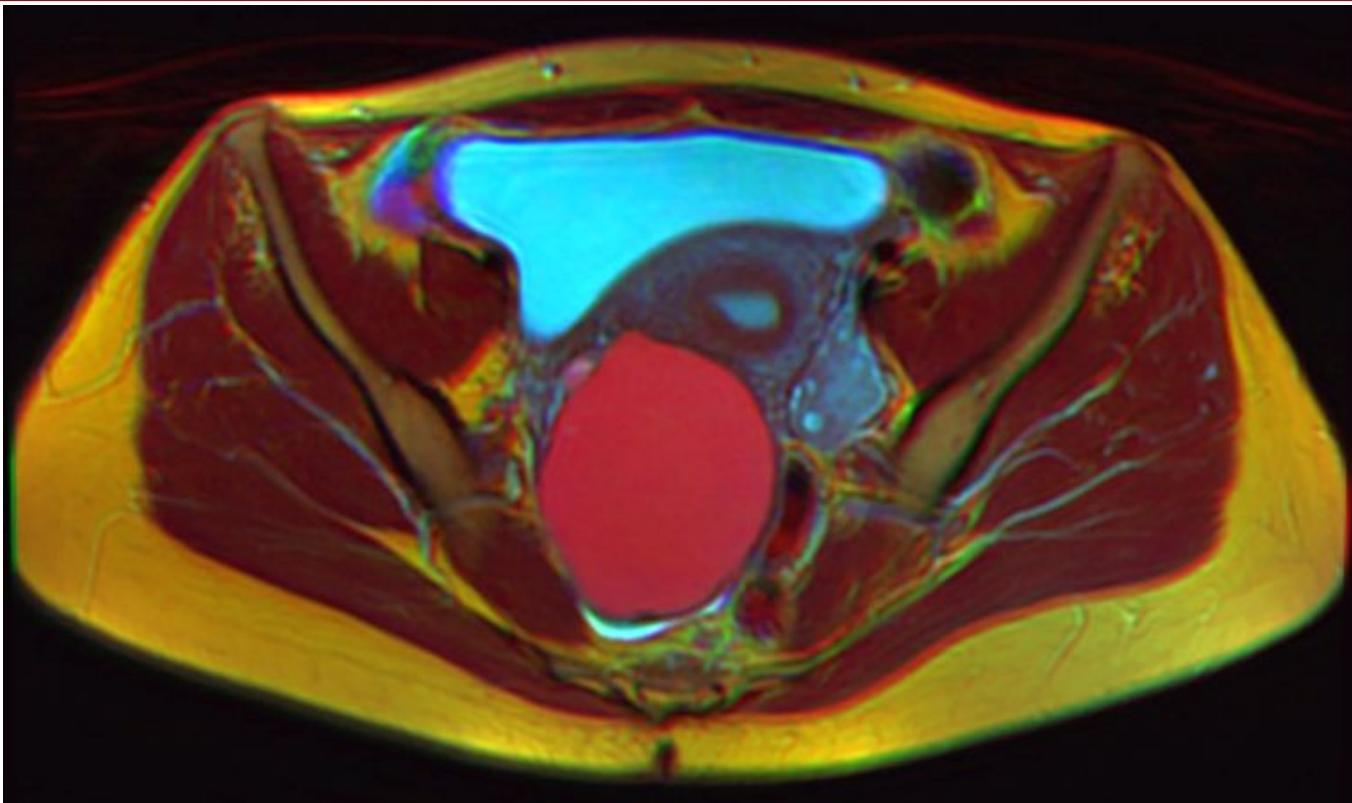
Lumbar



Endometrioma

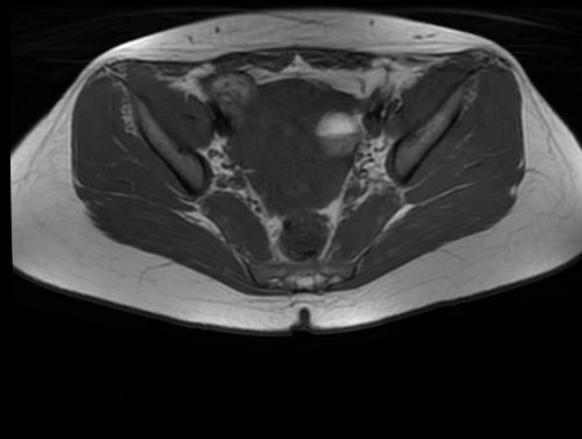


Endometrioma

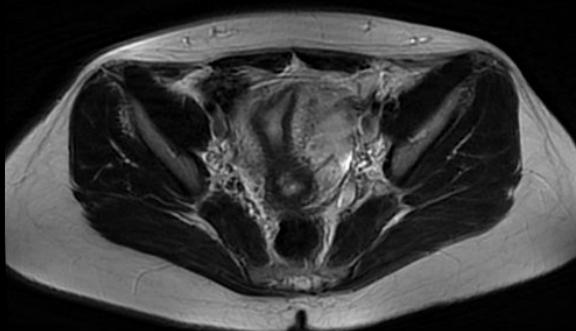


Dermoid cyst 1

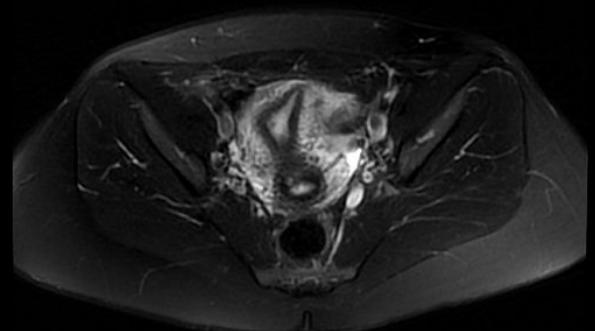
T1



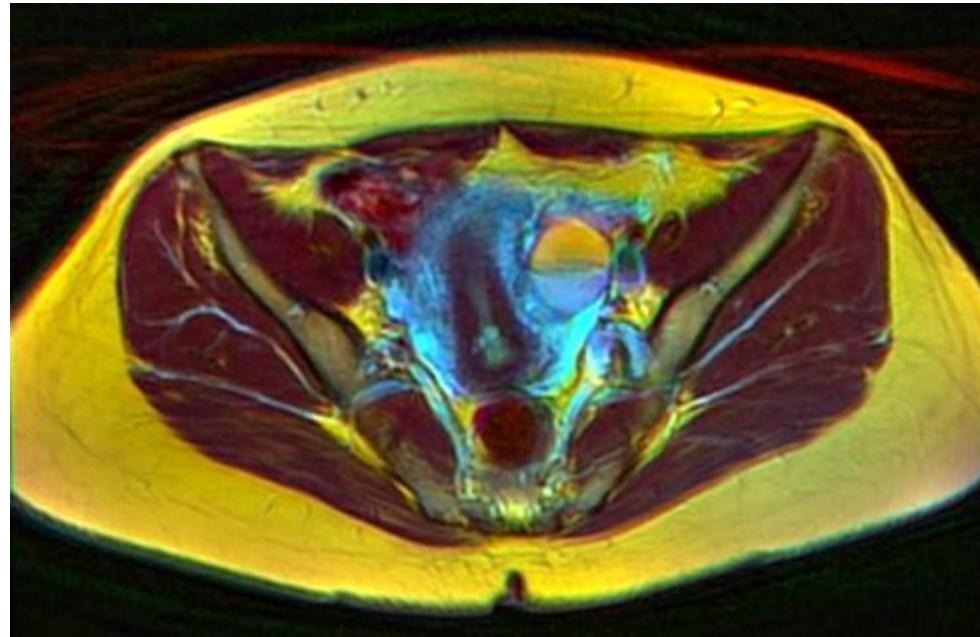
T2



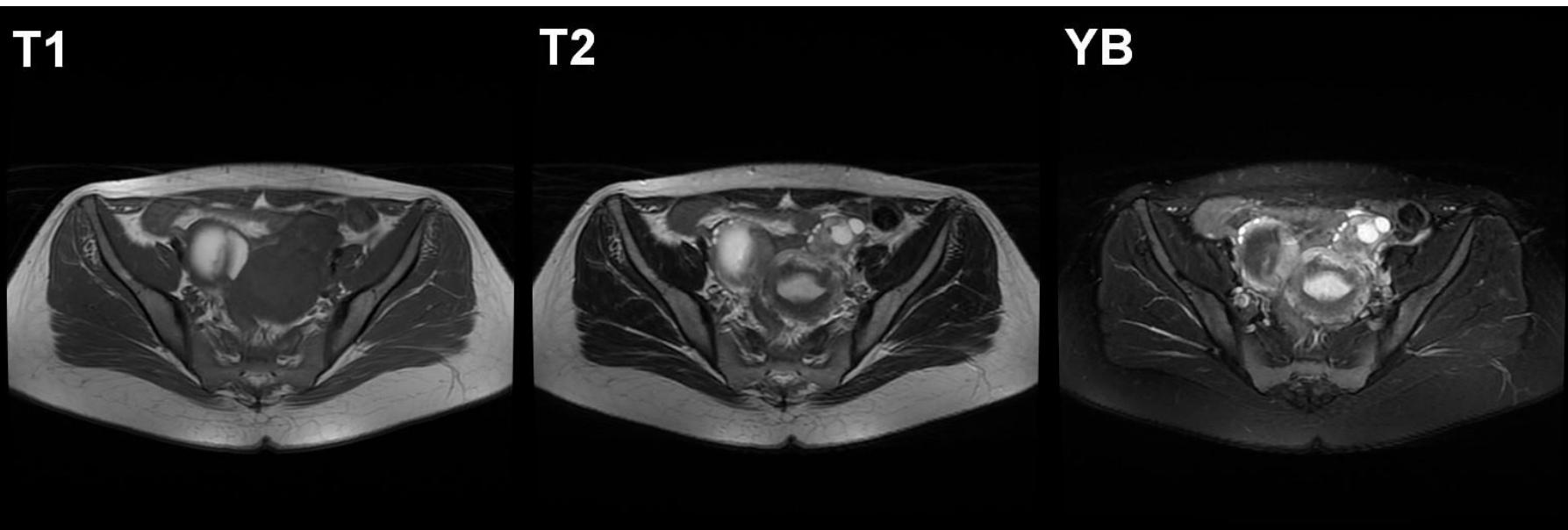
YB



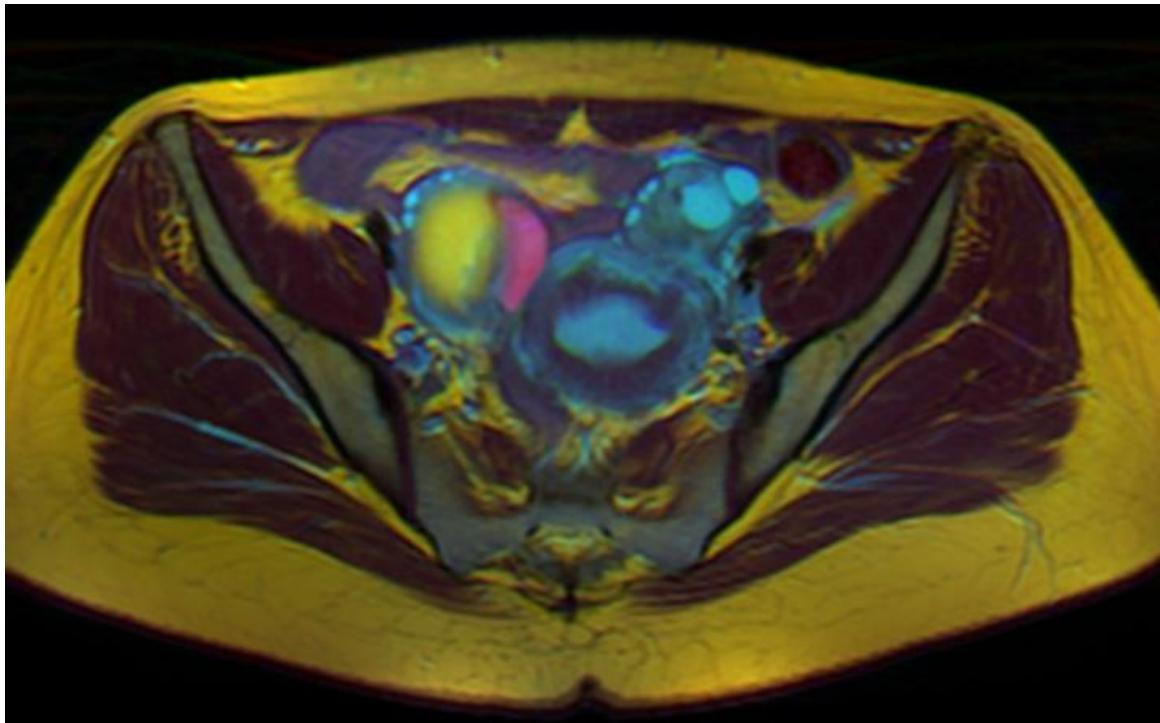
Dermoid cyst 1



Dermoid cyst 2



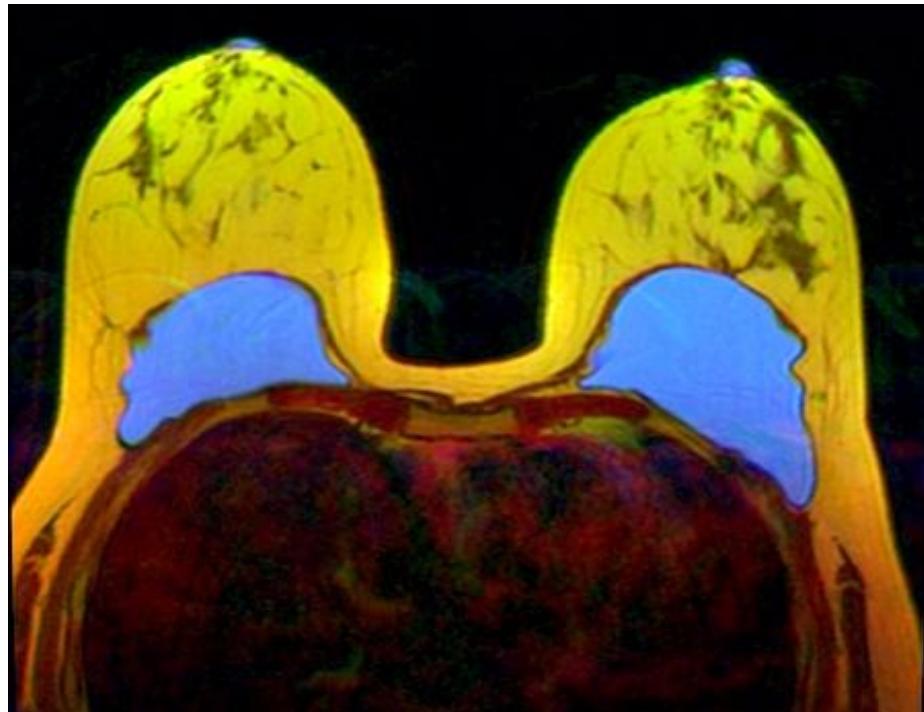
Dermoid cyst 2



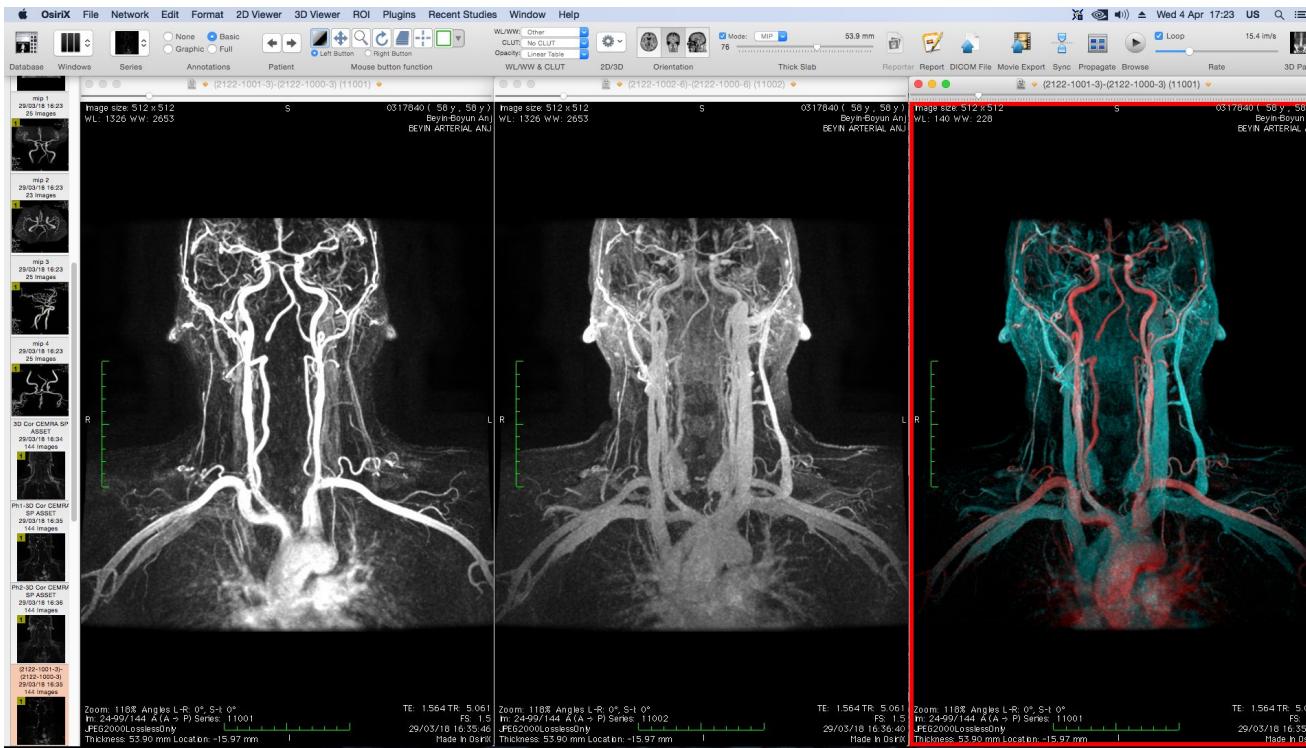
Orbita



Breast implant



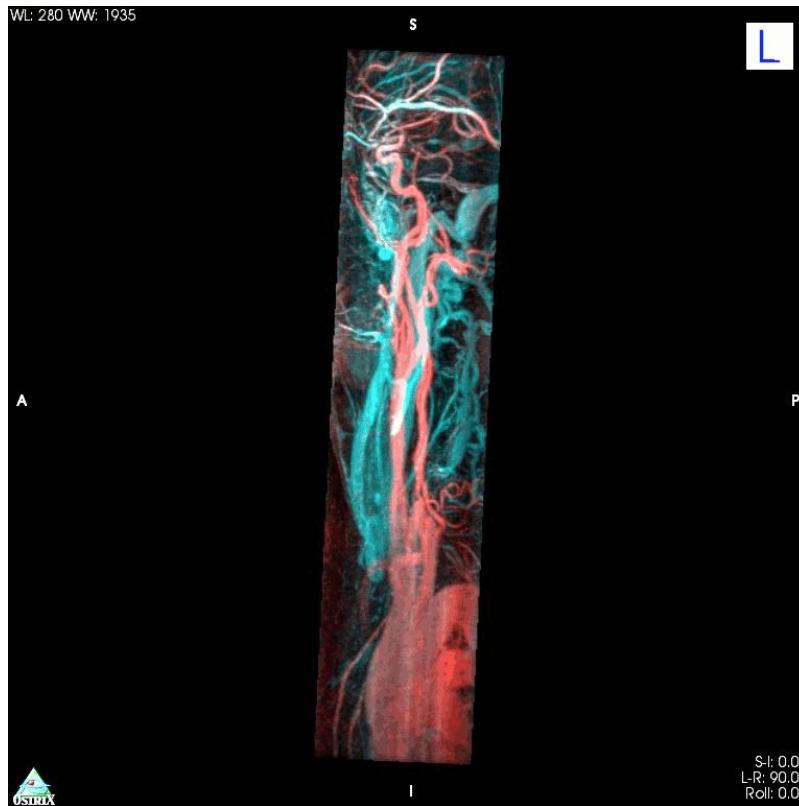
Color MRA (MR Angiography)



Arterial and venous phase in a single image.

Arterial phase > **R**
Venous phase > **G+B**

Color MRA (MR Angiography)



Milestones in MRI developments

Elektrik ile manyetizma arasındaki ilişkiyi kanıtladı	Ørsted (1820)
Elektrik ve manyetizma arasındaki temel denklemeler	Maxwell (1873)
Atom ve moleküllerin fiziği ve istatistiksel mekaniği	Maxwell (1860), Boltzmann (1872), Gibbs (1878)
Radyo dalgaları	Hertz (1887)
Süperiletkenlik	Kamerlingh Onnes (1911)
Rutherford Atom Modeli ya da Çekirdekli Atom Modeli	Rutherford (1911)
Kuantum kuramı	Bohr, Schrödinger ve diğerleri (1913–1926)
Pauli paramanyetizma	Pauli (1924)
Elektron spin hareketi	Uhlenbeck ve Goudsmit (1926)
Paramanyetik relaksasyon	Gorter (1936)
Nükleer manyetik rezonans deneysel gözleme	Rabi (1939)
Kati ve sıvılarda Nükleer manyetik rezonansın deneysel gözlenmesi	Bloch ve Purcell (bağımsız olarak, 1946)
Nükleer spin relaksasyon teorisi - T1 ve T2 'nin tanıtımı	Bloch (1946)
Nükleer manyetik rezonans da gevşeme mekanizmaları	Bloembergen, Pound ve Purcell (1948)
Spin echo	Hahn (1950)
High-field süper iletkenler. (High field-to-current ratio, Tesla/Amper)	Matthias, Kunzler ve diğerleri (1960)
Nükleer manyetik rezonansın Fourier dönüşümü	Ernst ve Anderson (1966)
X-ışınılı bilgisayarlı tomografi	Oldendorf (1961), Hounsfield (1973)
Tıbbi teşhis için tüm vücut NMR	Jackson (1968), Damadian (1972), Abe (1973)
Gradyan alanlarını kullanan manyetik rezonans görüntüleme (MRI)	Lauterbur (1973)
Seçici dilim uyarma	Mansfield (1974), Hoult (1977)
Gradyan alanlarını kullanan insan MRG	Aberdeen, Nottingham, EMI (1976–1979)
Alan'a odaklanan tüm vücut MRG	Damadian (1978)
Süper iletken tüm vücut mıknatıslarını kullanan yüksek alan (1,5 T) insan MRG	General Electric, Oxford Instruments (1981)
Multi Echo, multislice, spin eko, gradyan eko, spektroskopi, yüzey bobini ve diğer teknikler...	Birçok katılımcı (1980 – günümüz)

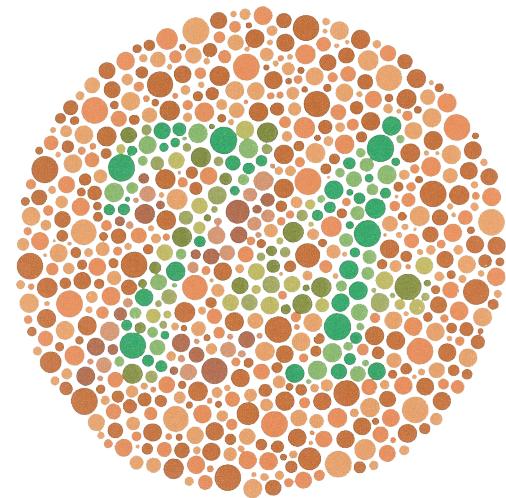
Color MRI
Color MRA

Now?
Future?
Never?

What might be the disadvantage of color MRI

There is a potential that physicians with color blindness might have problems with Color MRI.

Even if true, the source black and white images are still available for evaluation.



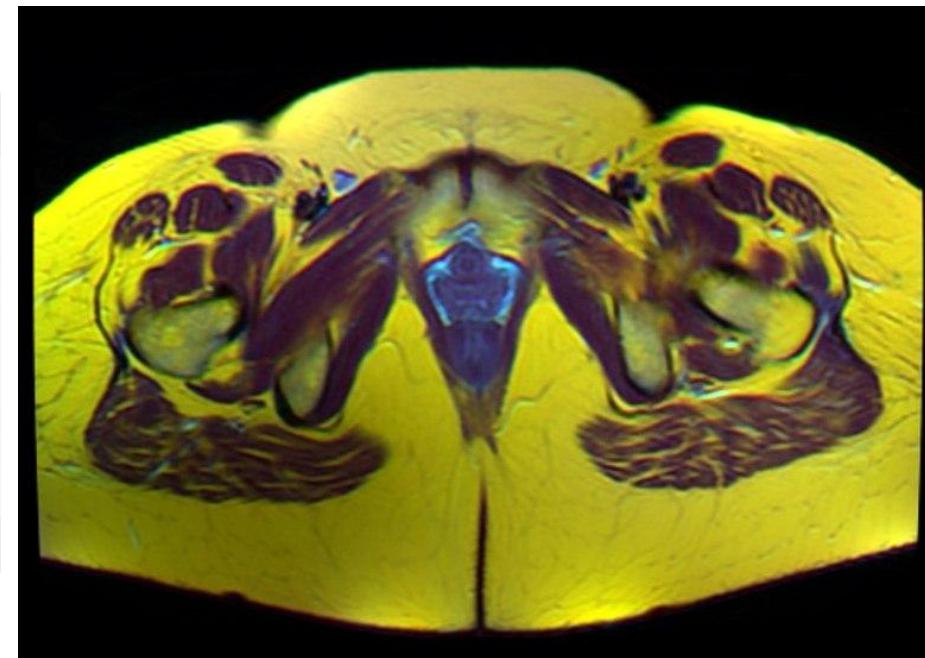
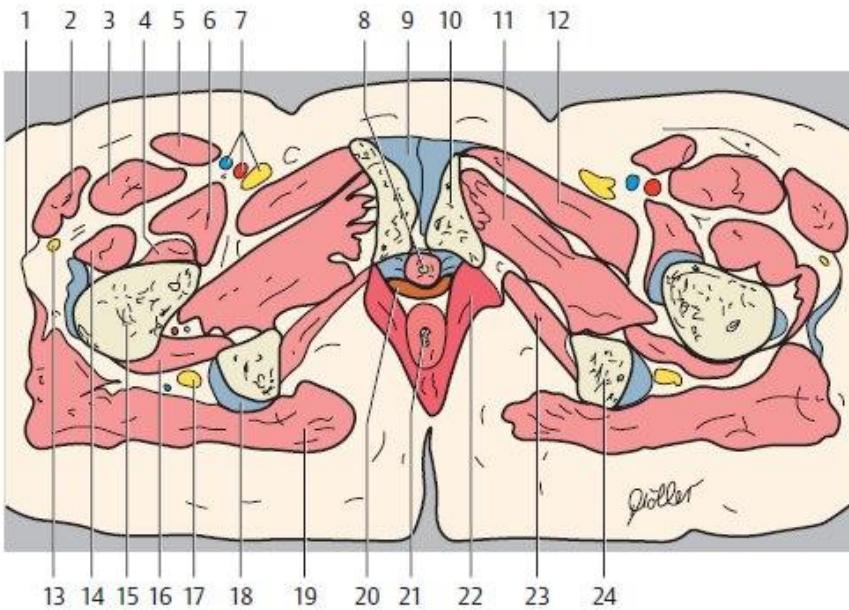
Screen and projection may affect the visibility of colors.

What's next?

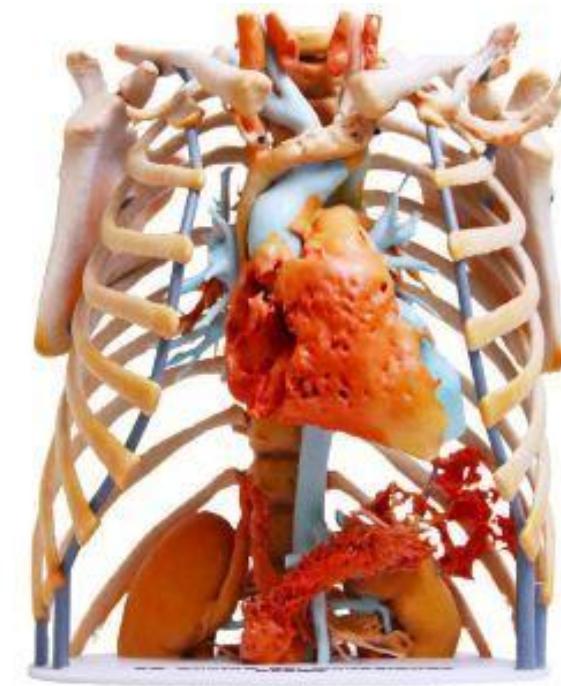
Future projects

"Creativity is combining facts no one else has connected before."
Christiane Nüsslein-Volhard 1995 Nobel Prize in Physiology or Medicine

Color MRI Atlas of Human Anatomy



Color 3D prints from Color MRI



Feed Color MRI as input to 3D Neural Networks

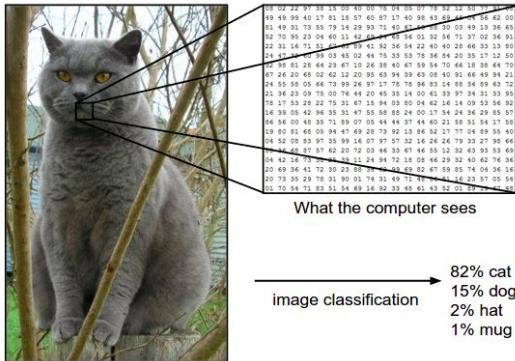
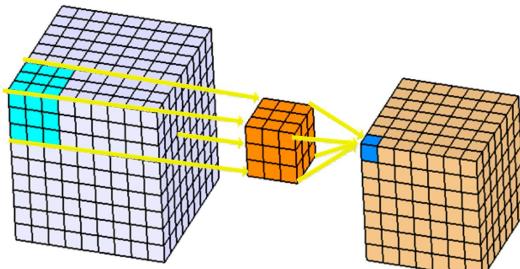
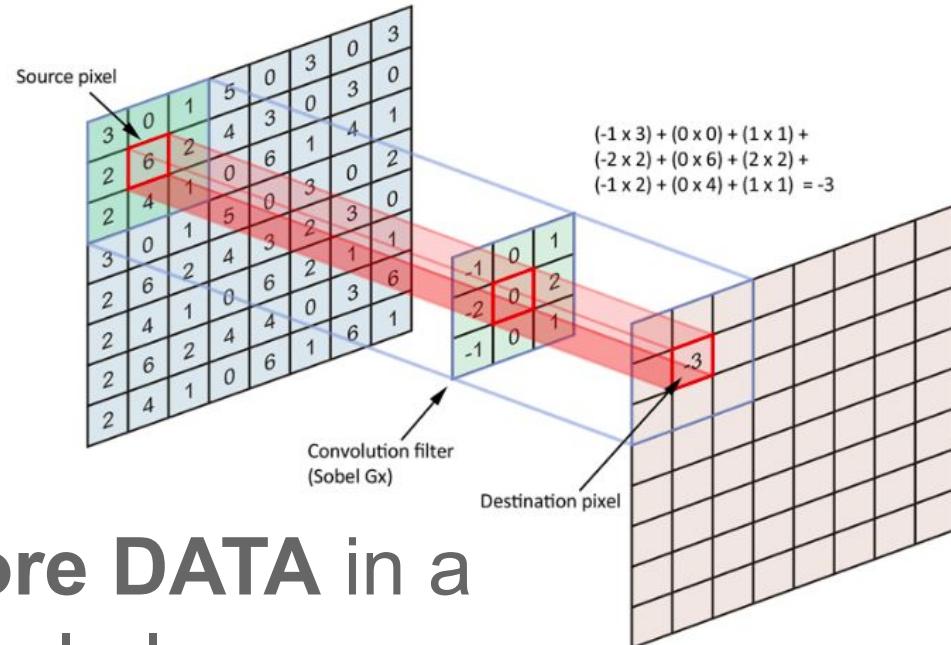


image classification →

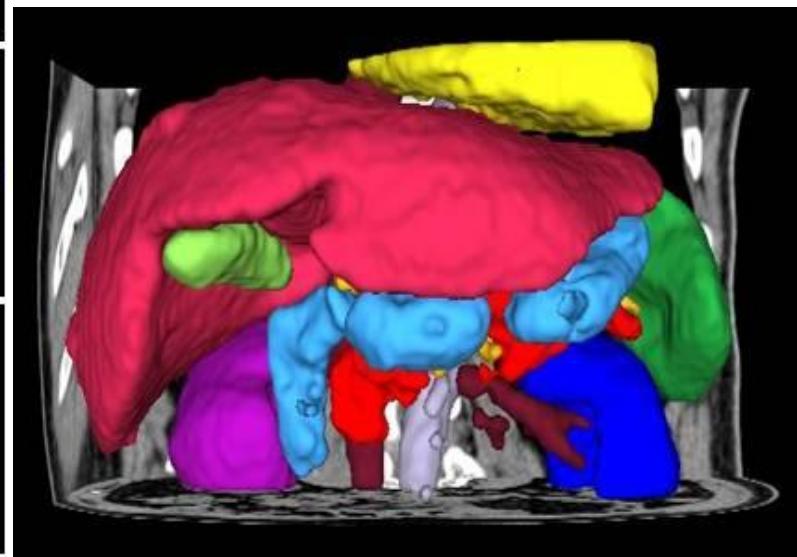
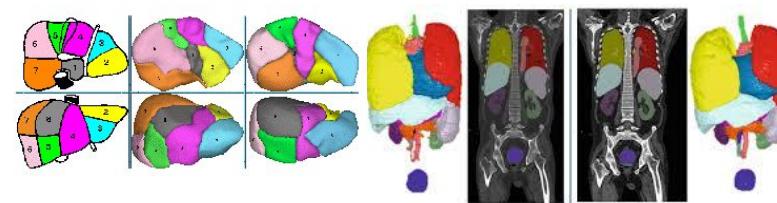
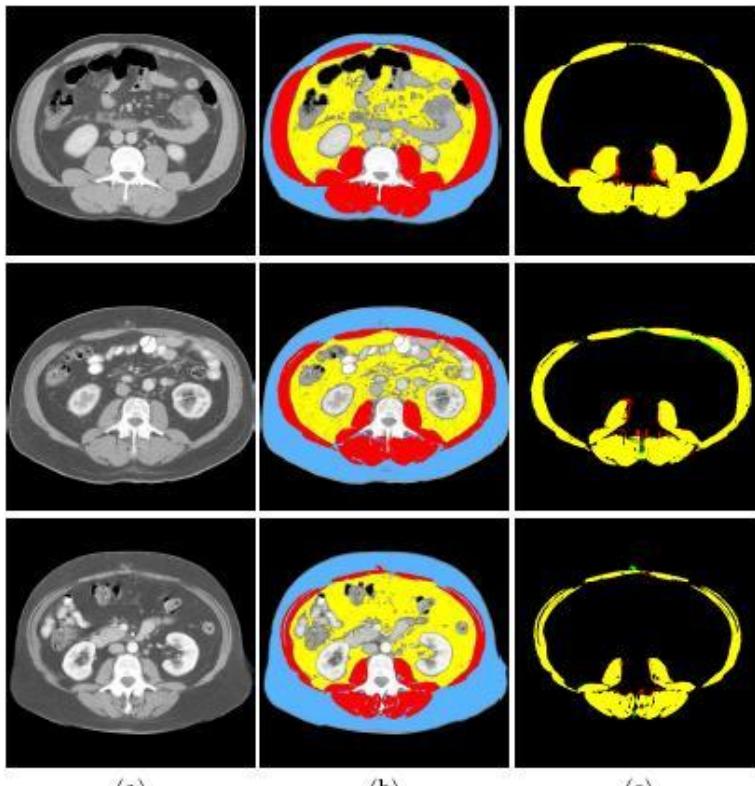


(Convolutional Neural Networks-CNN)



More DATA in a Single Image

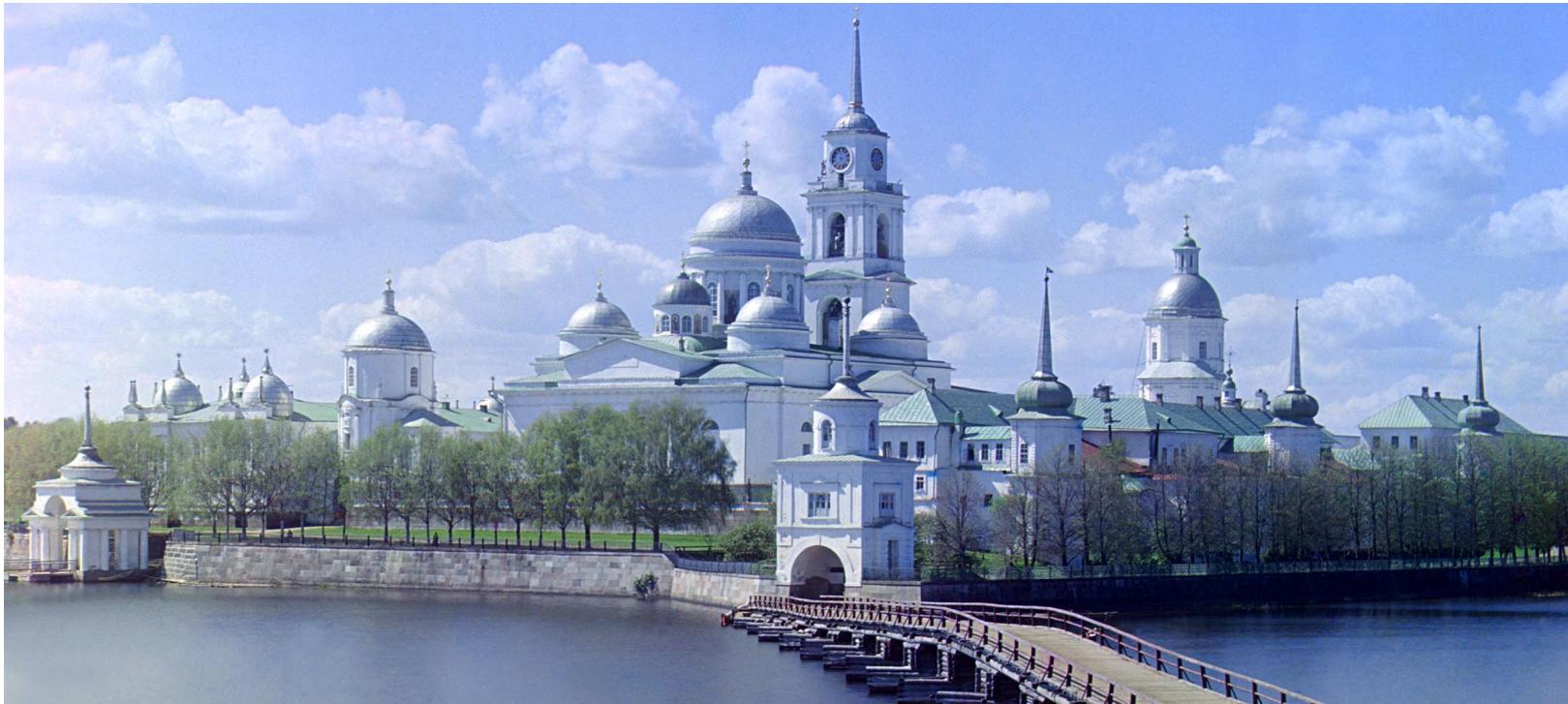
Segmentation and Labeling with Color MRI



Better Software

Let's talk about it

Thank you



Nilov Monastery, Stolobny Island, 1910, Gorskii

<http://bit.ly/NevitRMR>

Links

1. Google <http://www.google.com/search?q=nevิต+dilmen>
2. Yandex <http://yandex.com/yandsearch?text=nevิต+dilmen>
3. Linkedin <https://tr.linkedin.com/in/nevitdilmen>
4. <http://nevิต.blogspot.com/>
5. Twitter İngilizce <https://twitter.com/nevitdilmen>
6. Twitter Türkçe <https://twitter.com/nevitdilmenTR>
7. Youtube <http://www.youtube.com/user/fotografim/videos>
8. Pinterest <http://pinterest.com/nevitdilmen/pins/>
9. Örnekler https://commons.wikimedia.org/wiki/Category:False-color_MRI
10. Radiology Update <https://paper.li/nevitdilmen/1417970458>
11. Health Paper Daily <https://paper.li/nevitdilmen/1413056318>
12. İngilizce renkli MR ile ilgili bit.ly/Color_MRI
13. Bu sunum <http://bit.ly/NevitRMR>
14. Renkli MR yazılım sayfası <http://bit.ly/OsirixColorMRI>
15. <http://nevิต.deviantart.com/>

References

- W. E. Phillips, H. K. Brown, J. Bouza and R. E. Figueira, "Neuroradiologic MR Applications with Multiparametric Color Composite Display," *Magnetic Resonance Imaging*, Vol. 14, No. 1, 1996, pp. 59-72. doi:10.1016/0730-725X(95)02043-S
- H. K. Brown, T. R. Hazelton and M. L. Silbiger, "Generation of Color Composites for Enhanced Tissue Differentiation in Magnetic Resonance Imaging of the Brain," *American Journal of Anatomy*, Vol. 192, No. 1, 1991, pp. 23-34. doi:10.1002/aja.1001920104
- H. K. Brown, T. R. Hazelton, J. V. Fiorica, A. K. Parsons, L. P. Clarke and M. L. Silbiger, "Composite and Classified Color Display in MR Imaging of the Female Pelvis," *Magnetic Resonance Imaging*, Vol. 10, No. 1, 1992, pp. 143-154. doi:10.1016/0730-725X(92)90384-C
- M. G. Wells, P. F. Sharp and A. N. Law, "Principles and Appraisal of Combined Images in NMR," *Medical and Biological Engineering and Computing*, Vol. 27, No. 3, 1989, pp. 277-280. doi:10.1007/BF02441485
- K. L. Weiss, S. O. Stiving, E. E. Herderick, J. F. Cornhill and D. W. Chakeres, "Hybrid Color MR Imaging Display," *American Journal of Roentgenology*, Vol. 149, No. 4, 1987, pp. 825-829. DOI: 10.2214/ajr.149.4.825
- R. L. Kamman, G. P. Stomp and H. J. Berendsen, "Unified Multiple-Feature Color Display for MR Images," *Magnetic Resonance in Medicine*, Vol. 9, No. 2, 1989, pp. 53-55. doi.org/10.1002/mrm.1910090209
- H. K. Brown, T. R. Hazelton, A. K. Parsons, J. V. Fiorica, C. G. Berman and M. L. Silbiger, "PC-Based Multi-parameter Full-Color Display for Tissue Segmentation in MRI of Adnexal Masses," *Journal of Computer Assisted Tomography*, Vol. 17, No. 6, 1993, pp. 993-1005. doi:10.1097/00004728-199311000-0003