NeoBrainSeg : Segmentation de structures cérébrales de nouveaux nés

Élodie Puybareau

A l'origine...

The challenge of cerebral magnetic resonance imaging in neonates: A new method using mathematical morphology for the segmentation of structures including diffuse excessive high signal intensities.

Yongchao Xu[c,b,a], Baptiste Morel[d,b,a], Sonia Dahdouh[b], Élodie Puybareau[c,e], Alessio Virzì[b], Hélène Urien[b], Thierry Géraud[c], Catherine Adamsbaum[b,f], Isabelle Bloch[b]

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[c]EPITA Research and Development Laboratory (LRDE), Le Kremlin-Bicêtre, France
[d]Faculty of Medicine, François Rabelais University, Pediatric Radiology, CHRU Tours, France
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Abstract

Preterm birth is a multifactorial condition associated with increased morbidity and mortality. Diffuse excessive high signal intensity (DEHSI) has been recently described on T2-weighted MR sequences in this population and thought to be associated with neuropathologies. To date, no robust and reproducible method to assess the presence of white matter hyperintensities has been developed, perhaps explaining the current controversy over their prognostic value. The aim of this paper is to propose a new semi-automated framework to detect DEHSI on neonatal brain MR images having a particular pattern due to the physiological lack of complete myelination of the white matter. A novel method for semi- automatic segmentation of neonatal brain structures and DEHSI, based on mathematical morphology and on max-tree representations of the images is thus described. It is a mandatory first step to identify and clinically assess homogeneous cohorts of neonates for DEHSI and/or volume of any other segmented structures. Implemented in a user-friendly interface, the method makes it straightforward to select relevant markers of structures to be segmented, and if needed, apply eventually manual corrections. This method responds to the increasing need for providing medical experts with semi-automatic tools for image analysis, and overcomes the limitations of visual analysis alone, prone to subjectivity and variability. Experimental results demonstrate that the method is accurate, with excellent reproducibility and with very few manual corrections needed. Although the method was intended initially for images acquired at 1.5T, which corresponds to usual clinical practice, preliminary results on images acquired at 3T suggest that the proposed approach can be generalized.

Keywords: Neonatal brain MRI, preterm brain MRI, semi-automatic tissue segmentation, white matter hyperintensities, mathematical morphology, max-tree representation.

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Accepted in Medical Image Analysis

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But : fournir un logiciel de segmentation des différentes structures des cerveaux de nouveaux nés, et en particulier les hyperintensités, afin de pouvoir les analyser.

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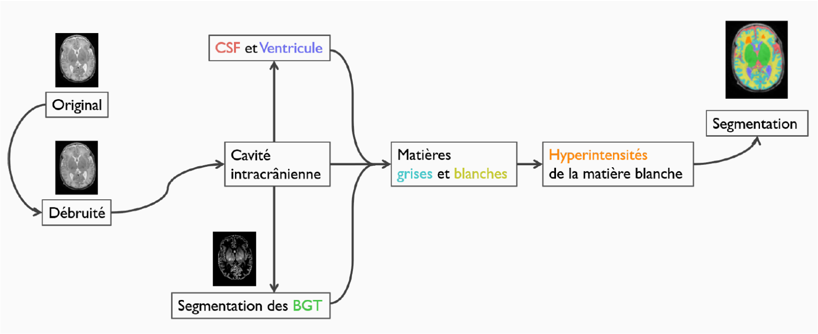
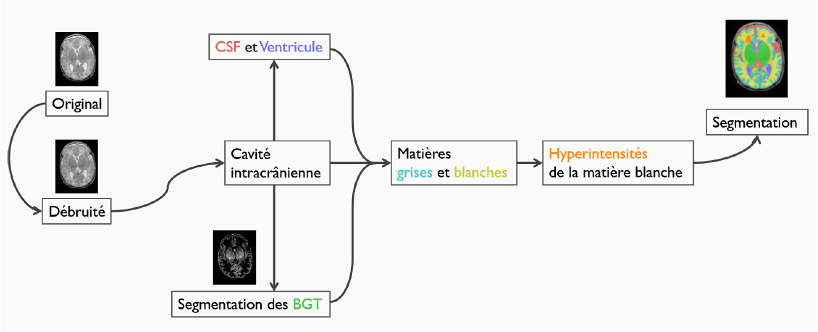
La pipeline


Original
Débruité
CSF et Ventricule
Cavité intracrânienne
Segmentation des BGT
Matières grises et blanches
Hyperintensités de la matière blanche
Segmentation

La pipeline



La segmentation se fait par étape, et est semi automatique : l'utilisateur place des marqueurs en fonction de la structure à segmenter.

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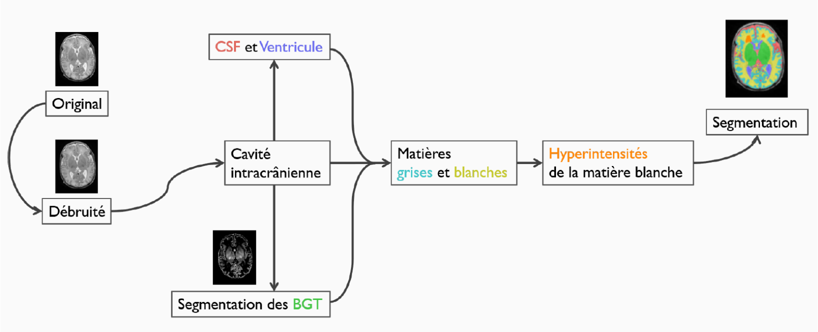
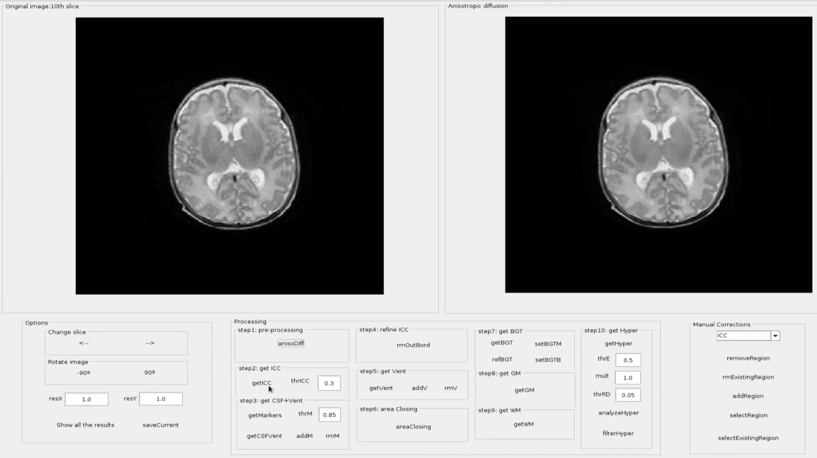


La segmentation se fait par étape, et est semi automatique : l'utilisateur place des marqueurs en fonction de la structure à segmenter. La méthode est basée principalement sur la morphologie mathématique.

Démo !


Original image:10th slice
Anisotropic diffusion
Options
Change slice
<--
-->
Rotate image
-90º
90º
resX
1.0
resY
1.0
Show all the results
saveCurrent
Processing
step1: pre-processing
anisoDiff
step2: get ICC
getICC
thrICC
0.3
step3: get CSF+Vent
getMarkers
thrM
0.85
getCSFVent
addM
rmM
step4: refine ICC
rmOutBord
step5: get Vent
getVent
addV
rmV
step6: area Closing
areaClosing
step7: get BGT
getBGT
setBGTM
refBGT
setBGTB
step8: get GM
getGM
step9: get WM
getWM
step10: get Hyper
getHyper
thrE
0.5
mult
1.0
thrRD
0.05
analyzeHyper
filterHyper
Manual Corrections
ICC
removeRegion
rmExistingRegion
addRegion
selectRegion
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Principe de base de nos procédures de Deep Learning

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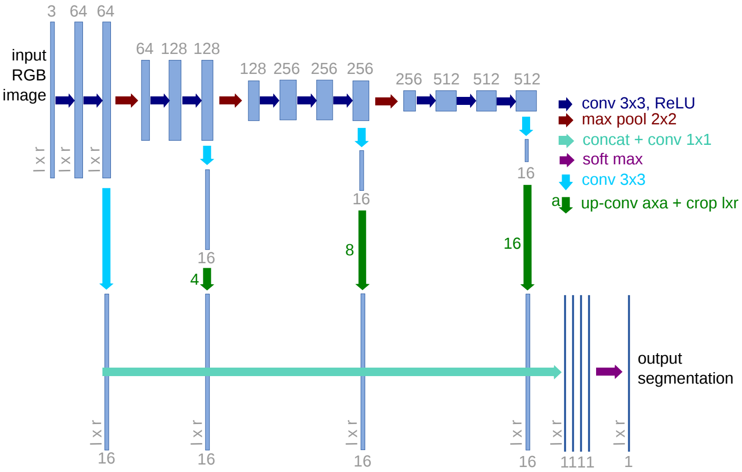
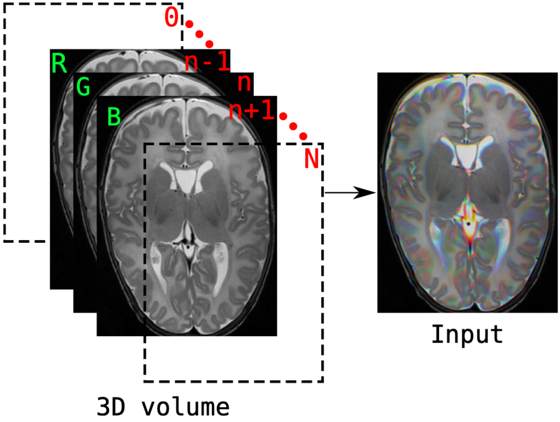


Principe de base de nos procédures de Deep Learning

Comment réussir à garder de l'information 3D en segmentant en 2D ?



2

2. T. Géraud, Y. Xu, I. Bloch, "From Neonatal to Adult Brain MR Image Segmentation in a Few Seconds Using 3D-Like Fully Convolutional Network and Transfer Learning", IEEE International Conference on Image Processing (ICIP), 2017

NeoBrain12

Challenge MICCAI "Neonatal Brain Segmentation 2012".

Dataset	Image set	# voxels	Size (mm^3)	Experiment (# images)	Code	Results		Timing
NeoBrain12	Axial / 40 weeks	512×512×50	0.35×0.35×2.0	2 training / 5 test T2	EXP1	Fig. 3(a)	Table 2 (top)	3.5 s
	Coronal / 30 weeks	384×384×50	0.34×0.34×2.0	2 training / 5 test T2	EXP2	Fig. 3(b)	Table 2 (mid.)	2.2 s
	Coronal / 40 weeks	512×512×110	0.35×0.35×1.2	2 + 2 training / 5 test T2	EXP3	Fig. 3(c)	Table 2 (bot.)	6.5 s

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Code	Method	CoGM		BGT		UWM		BS		CB		Vent		CSF	
		DC	MSD	DC	MSD	DC	MSD	DC	MSD	DC	MSD	DC	MSD	DC	MSD
Exp1	*Our*	**0.87**	**0.11**	0.91	0.51	**0.93**	**0.11**	**0.85**	0.49	**0.94**	0.33	**0.87**	0.24	**0.83**	**0.20**
	UPF_SIMBioSys [6]	0.85	0.15	**0.93**	**0.29**	0.91	0.17	**0.85**	**0.15**	**0.94**	**0.28**	0.83	0.44	0.79	0.29
	UNC-IDEA [9]	0.86	**0.11**	0.92	0.33	0.92	0.13	0.83	0.27	0.92	0.45	0.79	0.25	0.79	0.25
	5 next (median)	0.84	0.18	0.88	0.62	0.88	0.25	0.79	0.69	0.91	0.53	0.81	0.32	0.73	0.54
Exp2	*Our*	**0.79**	**0.14**	0.89	0.42	**0.95**	**0.14**	0.84	0.37	0.91	**0.30**	0.87	0.33	**0.89**	**0.13**
	UPF_SIMBioSys [6]	0.75	0.16	**0.90**	**0.38**	0.93	0.22	**0.86**	**0.32**	**0.92**	0.31	**0.88**	0.25	0.85	0.17
	CIMAT_Team	0.69	0.26	0.89	0.41	0.93	0.28	-	-	-	-	0.82	**0.22**	0.82	0.22
	5 next (median)	0.60	0.38	0.82	0.77	0.87	0.46	0.71	0.88	0.87	0.40	0.86	0.41	0.74	0.46
Exp3	*Our*	**0.79**	**0.21**	0.86	0.98	**0.91**	**0.18**	0.68	1.13	0.89	0.65	0.82	0.41	**0.82**	**0.30**
	MorphoSeg [7]	0.77	**0.21**	0.86	0.96	0.89	0.24	0.72	0.95	**0.91**	**0.55**	0.78	0.39	0.78	0.39
	UPF_SIMBioSys [6]	0.73	0.27	**0.89**	**0.52**	0.87	0.30	**0.76**	**0.53**	**0.91**	0.59	**0.85**	**0.34**	0.72	0.55
	5 next (median)	0.72	0.28	0.87	0.87	0.85	0.35	0.73	0.84	0.91	0.62	0.81	0.48	0.71	0.59

Cerveaux de 6 mois (phase isointense)

Idée : décliner l'idée du "pseudo-3D" en combinant les modalités. [3]

3. L. Wang et al. "Benchmark on Automatic 6-month-old Infant Brain Segmentation Algorithms : The iSeg-2017 Challenge", IEEE Transactions on Medical Imaging, 2019

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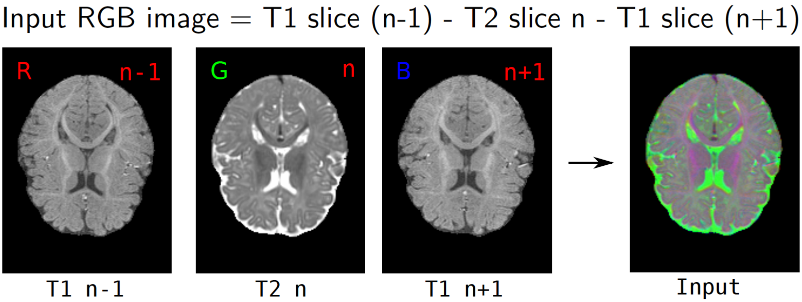

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Cerveaux de 6 mois (phase isointense)

- Results given by the LOSO procedure:

	WM	GM	CSF
Dice	0.86	0.881	0.920

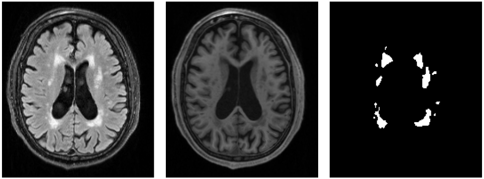
- Results given by the challenge:

	WM	GM	CSF
Dice	0.861	0.887	0.928
MHD	**6.607**	**5.852**	9.875
ASD	0.523	0.458	0.201

Ranking: **2nd over 21** and **1st over 21**

Hyper-intensités de la matière blanche

Dans le cadre de la détection de petites lésions dans le cerveau, les réseaux de neurones classiques ratent souvent les plus petites structures.



(a) FLAIR image (b) T1 image (c) Ground Truth

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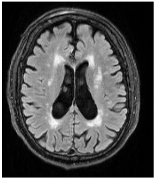
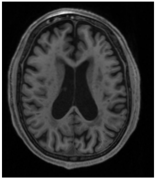
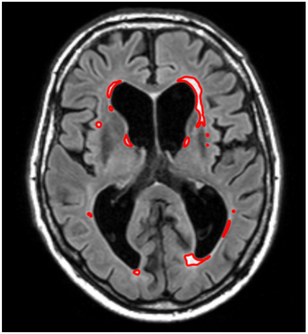


(a) FLAIR image



(b) T1 image

(c) Ground Truth



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Une solution est d'aider le réseau de neurones en lui donnant une information sur ces petites lésions. [4]

4. Y. Xu, T. Géraud, É. Puybareau, I. Bloch, J. Chazalon "White Matter Hyperintensities Segmentation In a Few Seconds Using Fully Convolutional Network and Transfer Learning", Brainlesion : Glioma, Multiple Sclerosis, Stroke and Traumatic Brain Injuries 2017

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Un outil de morphologie mathématique qui pourrait être utile dans ce cas est le top-hat.

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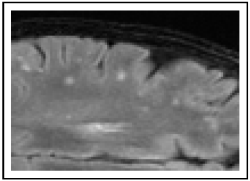
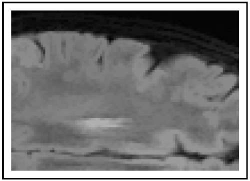


FLAIR



opening of FLAIR

top-hat

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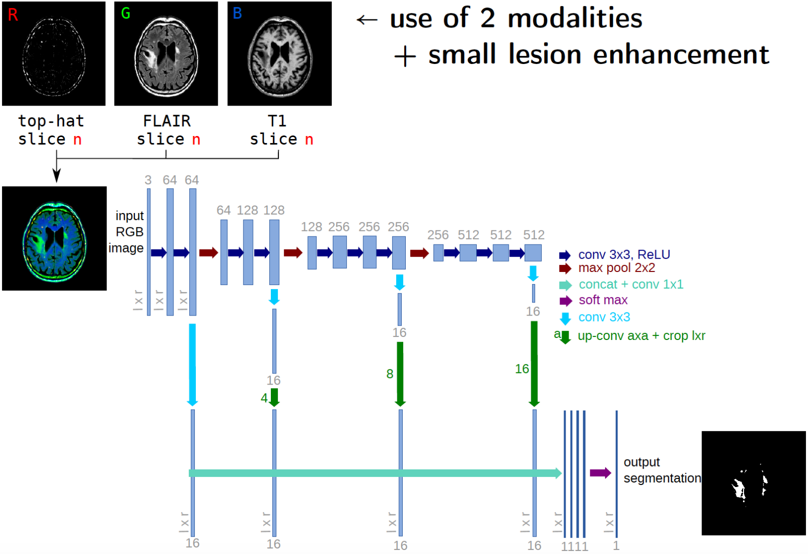
Hyper-intensités de la matière blanche

← use of 2 modalities
+ small lesion enhancement



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La combinaison des modalités avec l'image du tophat permet de mettre en évidence ces petites structures.

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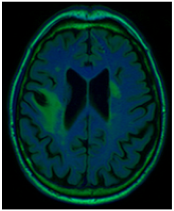
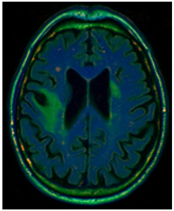


(d) Image en « couleurs » *sans* les éléments du *top-hat*



(e) Image en « couleurs » d'entrée

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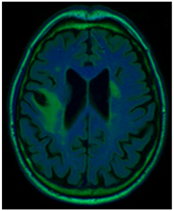

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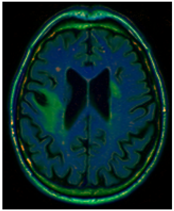

(e) Image en « couleurs » d'entrée

Type	Dice ↑	AVD ↓	Recall ↑	F1 ↑
pseudo-3D	0.72	23.90	0.38	0.46
2D without top-hat	0.72	28.24	0.39	0.48
2D with top-hat	0.75	22.63	0.61	0.63

↑ means the higher the better / ↓ means the lower the better

L'ajout de la partie "morphologie mathématique" permet d'améliorer significativement les résultats. On parle ici d'amélioration de la détection et non de la segmentation.

Deux étudiants dépoussièrent les vieux codes

Louis Gasnault : Conversion du code Matlab en Python.

OBJECTIFS DU SEMESTRE

- Nouvelle version, passage de `MatLab` à `Python`
- Utilisation de librairies récentes et maintenues
- Même qualité des résultats, recherche d'améliorations
- Partage du code
  - Open Source
  - Documentation / Code commenté

Deux étudiants dépoussièrent les vieux codes

William Guillet : Conversion du code Caffé en Pytorch.

Current Objectives

- Understand how an opening area works
- Implement this area opening
- Recover the top-hat image
- Understand how a convolution neural network works without the base layer.
- View the PyTorch library

Pour conclure

Nos objectifs :

5. https ://www.lrde.epita.fr/wiki/NeoBrainSeg

Pour conclure

Nos objectifs :

- Partager tous les codes que nous avons sur le sujet [5]

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- L'accès aux données

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- La bande passante

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- Les étudiants qui nous lâchent... et la difficulté à les recruter

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Nos points bloquants :

- L'accès aux données
- La bande passante
- Les étudiants qui nous lâchent... et la difficulté à les recruter
- Les "cobbayes" pour tester nos méthodes/interfaces

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