

Iterative watersheds and fuzzy tumor visualization

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Abstract

Our research deals with a semi-automatic tumor segmentation. Instead of trying to obtain an unlikely “perfect” segmentation, this method has a more realistic approach. To the classical “inside” and “outside”, we add a fuzzy area with a tumor probability between 0 and 1.

Figure 1 shows the principle of marker – based watershed segmentation [2] : image gradient is considered as a landscape with mountains where there is a high gradient and valleys where it is a low one. An immersion of this landscape with water flooding from two markers stops when their influence zone meet : this is the watershed line separating the two areas. Moreover, watersheds are calculated here using the gradient vector flow (GVF) instead of the classical gradient. The GVF [1] is a diffusion of the classical gradient which has here the interesting property to give more weight to the important edges, so results are less sensitive to noise : *Image 1*.

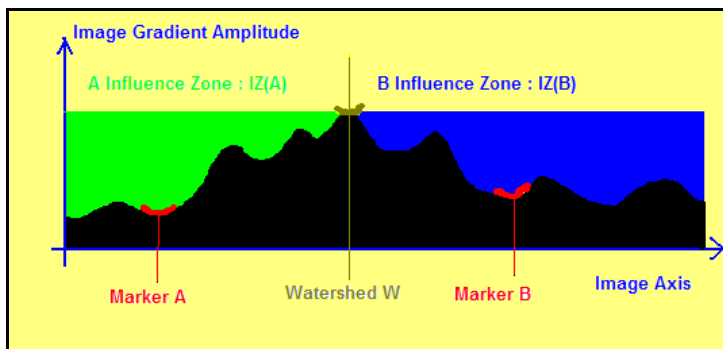


Figure 1 : Marker – based Watershed Principle

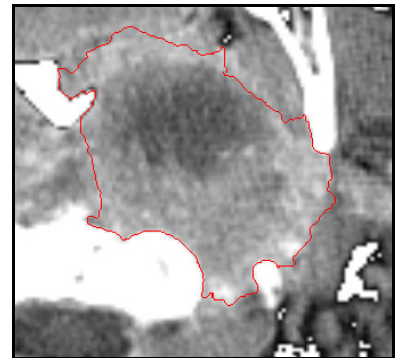


Image 1 : Watershed using GVF

Tests are made on real medical images of head and neck (CT, MRI and PET). Nevertheless this is a generic segmentation technique working on all kinds of tumors : the operator provides his model by using mouse clicks to get markers inside and outside the tumor. A first watershed is computed from this two initial marker sets (*Image 1*) and it is considered as a third marker for a second watershed (*Figure 2*) which gives three regions (inside, fuzzy and outside) : *Image 2*.

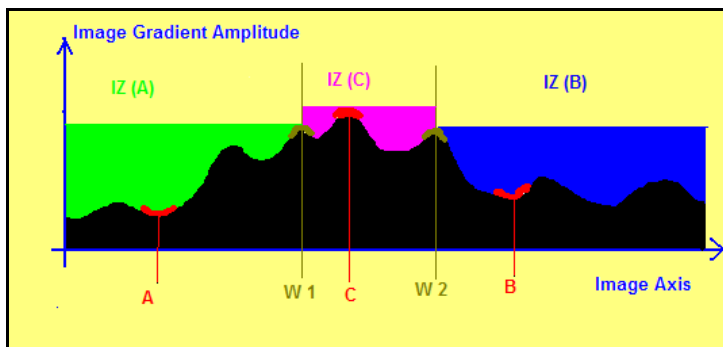


Figure 2 : Iterative Watershed (Level 1)

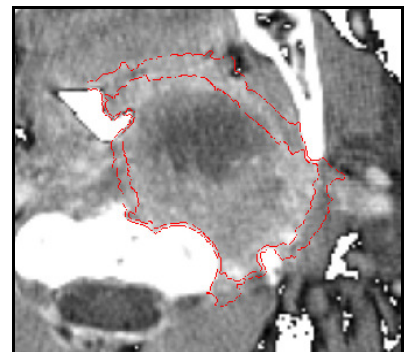


Image 2 : Fuzzy Visualization

This algorithm can also be used a second time (level 2) by adding to the previous markers the two sets resulting from level 1. We obtain five concentric regions from “inside” to “outside” with a decreasing tumor likelihood : *Images 3 and 5*.

At level 2, within the tests with our database, outside region does not include visible tumor and does not depend a lot on initial markers position. *Image 3* shows an example of a level 2 segmentation on a CT-scan slice. The corresponding slice (+/- 1 mm) after surgery on the patient (*Image 4*) shows the tumor as a white area invading muscles (red) and bones (white-yellow). We can see that the level 2 segmentation is very close to the real tumor.

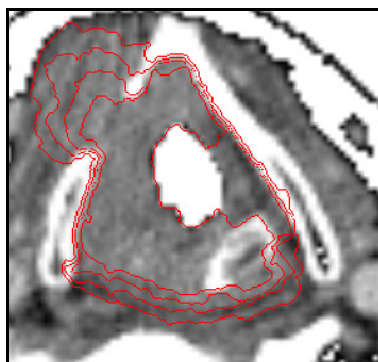


Image 3 : Level 2 segmentation on CT images



Image 4 : Corresponding slice after surgery

In addition to that, the watershed transform requires very low computation time by comparison to model based segmentation methods usually used in tumor visualization.

Our technique divides by three the average time spent by the operator during a manual segmentation : tests showed that it is necessary to perform 8 to 20 clicks per slice instead of 30 to 50 clicks. Moreover, the iterative watershed only needs clicks in

points where the operator has no doubt so, as no decision is necessary, he spends less time per click.

We tested the iterative watershed reproducibility on four very different tumors by computing the percentage of difference between the exterior region area (inside + fuzzy) when using different markers. The results are described in *Table 1* and were qualified as very encouraging by specialists.

	Tumor 1	Tumor 2	Tumor 3	Tumor 4	Total Average
Average difference at level 1	6.7 %	2.4 %	3.3 %	7.0 %	4.85 %
Variance at level 1	2.6	0.4	1.1	1.3	1.35
Average difference at level 2	7.4 %	4.0 %	4.0 %	6.8 %	5.55 %
Variance at level 2	2.0	1.8	2.0	1.0	1.7

Table 1 : Reproducibility test results

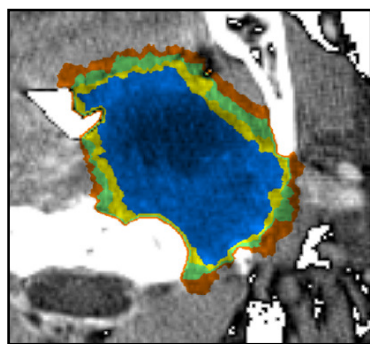


Image 5 : Level 2 with five regions and the fuzzy area (yellow + green + red)

Finally, if a tumor is near a bone, there will be high gradient and low ambiguity between them, so the fuzzy area will be narrower : *Image 5*. This information makes possible to predict the tumor evolution : it grows well in muscles but there are few chances for it to invade bones.

The visualisation of anatomical parts and more particularly pathological areas as tumors is a major issue in medical imaging. The specialists we met were very interested by this novel tumor visualization. They appreciated its more realistic fuzzy approach which reduces segmentation variability. Moreover, in a multi-modal context, CT, MRI or PET images can be more precisely mixed using fuzzy logic than for a classical inside/outside description.

Preliminary experiments are promising, but they still need validations. Future work will consist of a 3D extension of this method using slices interpolation. Finally, the tumor evolution prediction would be highly appreciated for radiotherapy planning.

Acknowledgements

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Reference

- [1] C. Xu and J. L. Prince, "Snakes, Shapes, and Gradient Vector Flow" *IEEE Transactions on Image Processing*, 7(3), pp. 359-369, March 1998.
- [2] J. Roerdink and A. Meijster, "The Watershed Transform : Definitions, Algorithms and Parallelization Strategies" *Fundamenta Informaticae*, 41, pp 187-228, 2001 IOS Press