Live-Wires on Egdes of Presegmented 2D-Data

Sebastian König and Jürgen Hesser

Institute for Computational Medicine, Universities of Mannheim and Heidelberg
68131 Mannheim, Germany
Email: skoenig@uni-mannheim.de

Abstract. In this article we present an extension to the Live-Wire segmentation approach. An automatic preprocessing is done before the interactive segmentation and thus provides an additional level of abstraction. The amount of the interactively processed data is reduced and additional problem specific knowledge is included. We achieve a data reduction of a factor of >6 for a typical MRT image of the human brain.

1 Introduction

The intention of our research is the fast segmentation of image data e.g. MRT images of the head, for example white and gray cerebral matter as well as smaller structures like the amygdala.

Our approach is based on Live-Wires that simply integrates the expert knowledge to solve ambiguous assignments of possible object borders.

To enhance the Live-Wire approach we restrict the possible segmented borders to edges of mosaic images having a twofold advantage: First, since the amount of nodes is reduced significantly, a corresponding speedup in processing can be achieved. Second, the generation of the mosaic image can incorporate problem-specific segmentation approaches.

2 Previous Work on Live-Wires

Edge-based segmentation uses the image-gradient as boundary for homogenous regions in the image [1]. Due to the interactivity Live-Wires allow to incorporate domain-knowledge with few user interactions only. The basic approach for Live-Wires is to find a cost-optimal path on a given graph, where the cost-function depends on the local image gradient. By defining seed points and roughly following the object boundaries, the expert restricts the possible solutions and the calculation (Live-Lanes) of the path to the relevant areas [2,3].

A typical approach to speed-up interactive segmentation is to split the segmentation task into an automatic oversegmentation of the image and an interactive step [4,5].

3 Fundamental Progress

In this paper we offer an extension to Live-Wire segmentation which is not only faster but also more problem specific. This extension is based on a preprocessing of the image that leads to a mosaic image. The borders of the mosaic areas are considered as edges in a graph. Instead of operating the live-wire on the image pixels as nodes we use the nodes from the constructed graph. With an adequate preprocessing step problem specific knowledge can be integrated that removes irrelevant edges from the whole process and thus speeds-up the interactive part.

4 Methods

In an automatic preprocessing step the image is over-segmented. Region-Growing, Watershed or combined methods are used in our example. This preprocessing step may be replaced or selected arbitrarily according to the intended application.

The result of the preprocessing is a mosaic. From this we extract the region borders and interpret them as a weighted undirected graph, defined in between the original image grid. Thereby, a node in the graph is given by the point where at least three mosaic region borders meet. Graph edges are given by those borders. Analogous to the static cost of the conventional Live-Wire method the weight of each edge is calculated from the gray-level gradient magnitude, gradient direction, and Laplacian zero-crossing that is accumulated along the edge.

The user interacts on the image which is to be segmented as in the standard Live-Wire approach. However, in this case we have to assign each mouse position in the image to its nearest node of the graph. As feedback, we highlight the chosen edges that are selected by the Live-Wire. As in the classical Live-Wire procedure the graph becomes a cost-tree, whose root is the chosen seed point. The algorithm calculates the piece-wise object boundary between the seed point and the current mouse position, using dynamic programming to identify the cost-minimal link between these nodes.

The classical optimizations, proposed to the Live-Wires, are also applicable to our approach and implemented, for instance, to calculate the cost field as far as it is needed or limiting the calculations to a user-defined region (Live-Lanes).

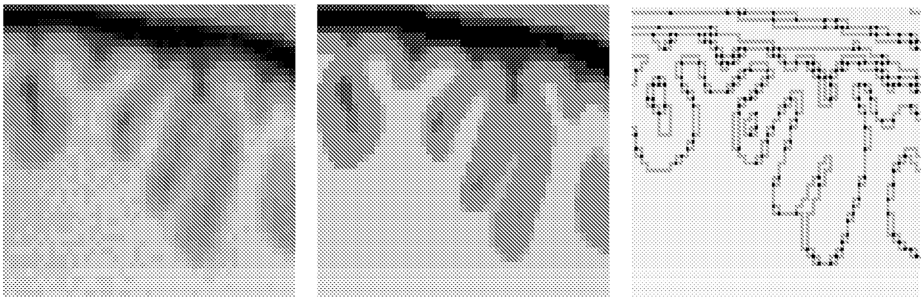
5 Results

Our software is implemented in Matlab (6.0.0.88 R12) on a PC with a 600 MHz Pentium III processor and 512 MByte RAM.

We choose a simple Region-Growing (centroid method, threshold value = 13, cf. [6]) as the preprocessing step in these examples. The threshold is adjusted so that at least every relevant object border is represented in the graph.

The results are shown in tables 1 and 2. Our approach is compared to the classical Live-Wire method onto two exemplary images, a synthetic test image (table 1) which demonstrates the capabilities of our approach and on an MRT

Fig. 1. On the left: A section taken from the MRT example image. Center: The therefrom calculated mosaic image. On the right: The graph, derived from the mosaic image. Nodes are plotted black, edges are plotted gray.



Note: In this example we focused on segmenting the boundary between the gray and white cerebral matter and adjusted the preprocessing accordingly. Other boundaries were not considered while adjusting the parameters and may not appear here.

Table 1. Results taken from a synthetic test image (256x256)

	A (classical)	B (new)
SIZE OF THE COMPLETE DATA SET		
absolute	65536 pixels	424 nodes
relative	100%	0.65%
CALCULATED COST FIELD ENTRIES		
absolute	48222 calculations (±36625)	612 calculations (±199)
relative	100%	1.27%
AMOUNT OF DATA USED DURING THESE COST FIELD CALCULATIONS		
absolute	6100 pixels (±4585)	265 nodes (±90)
relative	100%	4.34%

Table 2. Results taken from a MRT cerebral image (181x217)

	A (classical)	B (new)
SIZE OF THE COMPLETE DATA SET		
absolute	39277 pixels	4670 nodes
relative	100%	11.89%
CALCULATED COST FIELD ENTRIES		
absolute	59424 calculations (±7278)	8864 calculations (±1655)
relative	100%	14.92%
AMOUNT OF DATA USED DURING THESE COST FIELD CALCULATIONS		
absolute	8276 pixels (±910)	2668 nodes (±497)
relative	100%	32.24%

image of the brain[1] (table 2) as an example of a typical application. At this point we were interested in detecting the border between white and gray matter.

The tables contain the data set size, the amount of cost field entries that are calculated, and the amount of data elements that are required for the calculation of these cost fields. The latter two items are important to evaluate these results. They affect the required calculation time to perform the interactive segmentation substantially. This calculation time is nearly proportional to the number of cost field calculations, independent of the actual implementation or hardware equipment. The calculation of such a cost field entry requires about 0.8 milliseconds with our system, both with the classic Live-Wire method as well as with our new approach. The amount of time required in the preprocessing step is about 3.5 minutes.

6 Discussion and Future Work

It is fundamental for the achievable segmentation quality that all relevant boundaries are covered by the graph, since it defines the only edges that can be selected during the interactive phase. Furthermore, algorithms based on the search for a cost-optimal path tend to cut off corners and to shortcut in narrow notches. These problems are solved by our approach provided that such shortcuts are not offered by preprocessed boundaries. By adjusting the parameters of the preprocessing step the user is able to minimize this source of errors.

In addition to the Region-Growing based preprocessing step used here, Watershed based presegmentations were analyzed, as well. In comparison with the Region-Growing method, however, they provide slightly worse results. They provide about 1.2 times more nodes, covering the same minimum boundary, and cause much more shortcuts in notches. The amount of the data processed interactively and the number of calculated cost field entries were strongly reduced and the segmentation was accelerated by a factor of about 6.7 .

As the interactive segmentation occurs on the abstract graph level it is tolerant to inaccuracies in user interaction. In segmenting our cerebral image, for example, it is possible to trace the boundary between gray and white matter by selecting only six graph nodes as seed and support nodes. We intend to make use of this tolerance together with the enhanced processing speed to extend our Live-Wire approach into the third dimension, making the step from active contours to active surfaces.

References

1. O'Donnell L, Kikinis R et al.: Phase-Based User-Steered Image Segmentation. MICCAI, 2001.
2. Mortensen E N, Barrett W A: Interactive Segmentation with Intelligent Scissors. Graphical Models and Image Processing, no. 60, pp. 349-384, 1998.

[1] A T1 weighted volume data set taken from the BrainWeb database. [7]

3. Falcao A X, Udupa J K, Miyazawa F K: An ultra-fast user-steered image segmentation paradigm: Live wire on the fly. COX, 19(1):55-61, 2000.
4. Kühne G, Poliwoda C, Hesser J, Männer R: Interactive Segmentation and Visualization of Volume Data Sets. Late Breaking Hot Topics, Visualization pp. 9-12, 1997.
5. Keeve E et al.: 3D Markov Random Fields and Region Growing for Interactive Segmentation of MR Data. MICCAI, 2001.
6. Adams R, Bischof L: Seeded Region Growing. IEEE Trans. on PAMI, Vol.16, No.6, pp.641-647, 1994.
7. BrainWeb: Simulated Brain Database. http://www.bic.mni.mcgill.ca/brainweb/