Images registration by discontinuous correspondence calculated iteratively using graph cuts

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Keywords: registration, steepest descent, graph cut, total variation, **L1** norm

3D reconstruction of biological objects from microscopic images requires registration of misaligned physical sections and sometimes also correction of deformations or fissures in the sections caused by slicing. While the deformations can be dealt with by an elastic registration [1], correction of the fissures requires prior information on the discontinuous correspondence between images of the neighboring sections.

The correspondence between the images can be found by minimization of a functional penalizing the dissimilarity of corresponding image elements together with roughness of the correspondence function. We chose **L1** norm as a measure of dissimilarity of images and the total variation as a measure of roughness. Let *Pix* be the set of image elements (pixels) and *Edg* the set of edges connecting neighboring pixels. Let u and v be the images of neighboring sections and let ξ be a vector valued image coding the correspondence. As the minimized functional we used

$$F(\xi) = \sum_{e \in Edg} \left|\xi^1_{e_1} - \xi^1_{e_2}\right| + \left|\xi^2_{e_1} - \xi^2_{e_2}\right| + \frac{1}{\lambda} \sum_{p \in Pix} \left|u_{p+\xi} - v_{p-\xi}\right|$$

where $\lambda > 0$ is the parameter controlling the trade-off between the smoothness of correspondence and similarity of corresponding image elements. The functional can be minimized by an iterative steepest descent method [2] finding in each step of the iteration for a fixed vector δ the set of pixels $S \subseteq Pix$ such that the change of ξ to $\xi + \delta I_S$ yields the maximum decrease in the value of the functional F. The set S was found by graph cut minimization [3]. As the values of δ we used values of decreasing modulus and alternating directions $(\pm 2^n, \pm 2^n)$, $(\pm 2^n, 0)$, ..., $(\pm 1, \pm 1)$, $(\pm 1, 0)$, $(0, \pm 1)$. The functional F is not convex and so the existence of the global minima ξ is not guaranteed. The result of minimization can thus depend on the sequence of values of δ.

The combinatorial method of minimization searching the set of pixels to a given shift, instead of more straightforward approach searching the proper shift for each pixel, is fast and robust.

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This research was supported by grants AV0Z 50110509, A100110502, GAČR 102-08-0691, LC 06063. The aid of Dr. Kundrát and Dr. Michálek is gratefully acknowledged.

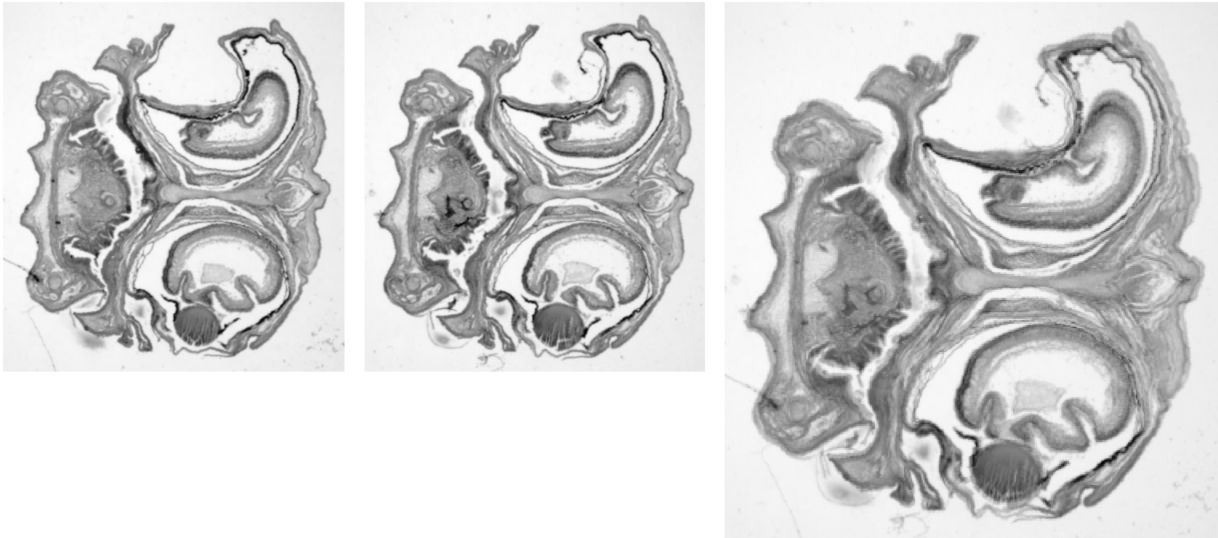

Figure 1. Images of neigbouring sections of turtle embryo head and their average before registration. Images were provided by Dr. Kundrát (SAV, Slovakia).

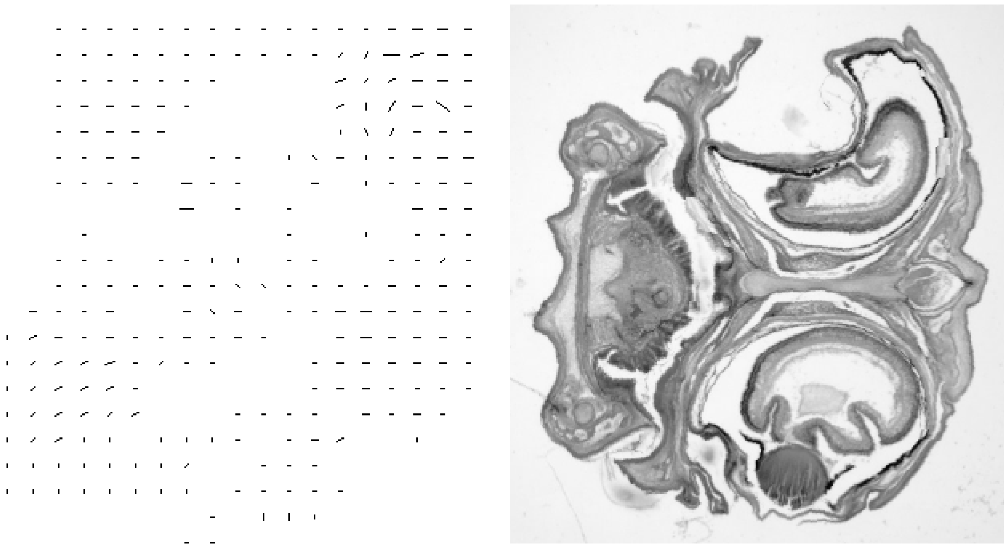

Figure 2. Correspondence field by segments and average of images from Fig. 1 after registration using discontinuous correspondence. The registration was successful even in the difficult region between the skull (right) and jaw (left).

M.A. Pabst, G. Zellnig (Eds.): MC2009, Vol. 2: Life Sciences,
DOI: 10.3217/978-3-85125-062-6-355, © Verlag der TU Graz 2009