Multigrid Optical Flow for Deformable Medical Volume Registration

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In medical imaging, a need often arises to compare images or volumes in a time series. For example, one approach to improving cancer detection acquires a sequence of volumes while injecting a contrast agent. Differences in the uptake of the contrast agent can differentiate potential malignancies from normal tissue.

However, motion of the patient between volume acquisitions means that the volumes need to be registered before they can be compared. In the case of soft tissues, deformable registration is required.

We will present a deformable registration algorithm that is robust to changes in contrast and uses both multigrid and many-core parallelism for high performance.

Optical Flow

Optical flow is one approach to computing a deformable registration. Computation of optical flow requires finding a deformation of one volume (the moving volume) that satisfies the optical flow equation, which is given as a constraint on differentials:

$$E_r \cdot r_t + E_t = 0.$$

Here E is the 4D space-time volume (3 spatial positions, indexed by the vector r, and one time dimension). Subscripts indicate partial derivatives. The vector r_t indicates the deformation as a function of time.

However, the optical flow equation underconstrains the solution, so an additional regularization constraint that specifies a smooth solution also needs to be included.

Solution Algorithm

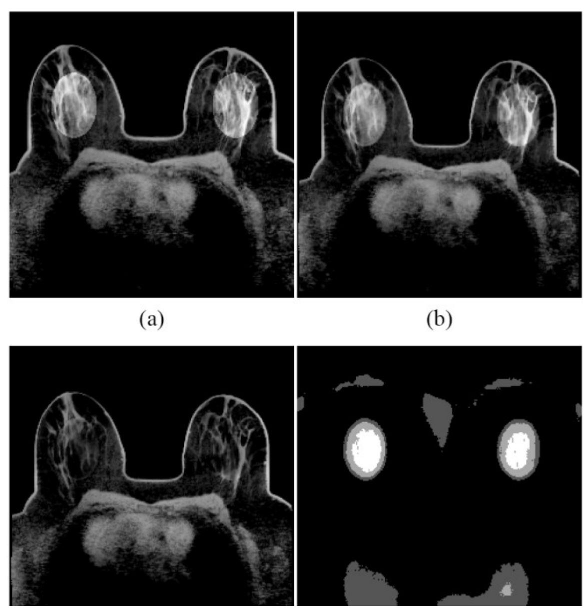
Finding a solution to the optical flow equation is done iteratively. During each iteration, the moving volume must be resampled with the current deformation and must be smoothed with a convolution in order to compute the regularization. Differential operators must also be computed, in particular the gradient of the fixed image

Extensions and Results

Optical flow can be an expensive algorithm when applied to a large number of high-resolution volumes. In addition, the basic formulation of the optical flow algorithm does not actually allow for brightness changes other than those induced by motion. Of course, in applications of interest, such as contrast agent injection, such changes are present. In fact, the goal is often to *differentiate* such contrast changes from those due to motion.

We will present an extension of optical flow that allows for contrast changes, while still computing an accurate deformation. This extension does not add significant computational overhead. In addition, we will present the results of many-core parallelization combined with the use of a multigrid extension to optical flow. Together these optimizations improve the performance of the baseline algorithm by two orders of magnitude.

Results computed by our algorithm are shown in the image below. Multigrid not only significantly improves performance, it also leads to more accurate and robust solutions.



Top: (a) fixed image (b) moving image. Bottom: (a) registered volumes with contrast removed (b) recovered contrast. Dataset courtesy of Sentinelle Medical.

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