Calculus of variations is a unifying framework for a wide spectrum of computer vision problems. Numerous existing algorithms have been shown to have variational explanations, and variational or geometric considerations gave rise to many new powerful algorithms. As a research direction for my Ph.D. studies, I propose to explore several facets of variational methods in computer vision.

The first facet is devoted to the so-called fast marching methods (FMM). Fast marching methods is a generic name of numerical schemes for computing solutions to the nonlinear Eikonal equation and related Hamilton-Jacobi equations. Based on entropy-satisfying upwind schemes, they yield consistent, accurate, and highly efficient algorithms. They are optimal in the sense that the computational complexity of the algorithms is $O(N \log N)$, where $N$ is the total number of points in the domain. In his seminal work, Sethian (1996) proposed an efficient algorithm for solution of the Eikonal equation on domains with simple weighted Euclidean metric. A similar algorithm was developed by Tsitsiklis (1995). The basic fast marching method was later generalized for arbitrary triangulated manifolds (Kimmel and Sethian, 1998), parametric manifolds (Spira and Kimmel, 2004), and implicit unorganized surfaces (Memoli and Sapiro, 2001).

Almost a decade since their introduction, fast marching schemes, together with the level set methods (Osher and Sethian, 1998), have become state-of-the-art tools in a variety of applications, including problems in shape offsetting, shape-from-shading, photolithographic development, computing first arrivals in seismic travel times, construction of shortest geodesics on surfaces, optimal path planning in robot navigation, visibility and reflection calculations in robot vision and computer graphics, computational fluid dynamics, segmentation and tracking, variational processing of images, construction of isometric-invariant representations of objects, and face recognition, to name a few. As a part of my Ph.D. research, I propose to explore several aspects of FMM and their applications.

The work on expression-invariant three-dimensional face recognition (3DFACE, 2005) has shown that although their theoretical efficiency, fast marching schemes do not suit ideally
to existing CPU architectures. Different update strategies should be thought of in order to achieve efficient utilization of cache and memory resources and to allow parallelization. Our preliminary results show almost an order of magnitude improvement in performance of a slightly suboptimal version of the parametric FMM on commodity Intel and AMD processors. Another important issue poorly addressed in the literature is robust fast marching schemes for low-precision arithmetics (e.g. 16-bit fixed point or integer) for the use in embedded systems and commodity DSP processors. I believe this will help efficient FMM-based solutions to enter many applications, where they have not been used so far due to technological limitations.

Many applications, where fast marching and level set methods are commonly used, favor multi-resolution algorithms. Multi-resolution or multigrid-favored strategies might allow to develop more efficient fast marching schemes for such problems. In addition, I propose to explore the fast multipole approach for approximate computation of distance maps in very large-scale problems, where standard FMM are infeasible due to computational complexity reasons.

Last but not least, numerous applications of FMM and level sets require distance computation on volumetric or spatio-temporal data (e.g., segmentation of CT or MRI volumetric medical images, segmentation and tracking of objects in video sequences). This requires solution of the Eikonal equation on three-dimensional manifolds, for which no numerical schemes are currently available. As one of the facets of my Ph.D. research, I propose to fill this apparent gap, and show immediate applications in medical imaging and face recognition.

As a second facet of my Ph.D. research, I propose to explore variational formulations of dense optical flow field estimation problems and their applications to stereoscopic vision. Recent works by Bruhn, Weickert and Schnörr (2002) show that classical results by Horn and Schunck (1996) and Lucas and Kanade (1981) fit a single unifying variational framework. I propose to extend this framework for solving the problem of dense disparity field estimation and consequent range reconstruction in stereoscopic video sequences. Variational formulation will allow to incorporate both geometric priors on the reconstructed three-dimensional object, and temporal priors for smooth changes thereof. As part of this research, I propose to build a real-time stereoscopic imaging system and develop efficient algorithms for variational dense range estimation. From recent works by Bruhn, Weickert and Schnörr (2003), it appears that multigrid techniques can make feasible real-time implementation on commodity CPUs.
Bibliography


**Curriculum Vitæ**

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- Born: May 28, 1980, Russia
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**Degrees**
- January 2005 (expected) M.Sc., Electrical Engineering, Technion
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- 2004 Kasher prize (project supervision)
- 2003 Kasher prize (project supervision)
- 2003 Excellence Program alumnus
- 2003 Counter Terrorism Gensler prize
- 2003 Hershel Rich Technion Innovation award
- 2003 Honorary student delegate, International Achievement Summit (Washington D.C.)
- 2003 Technion Graduate School excellence scholarship
- 2002 Thomas Schwartz prize
- 2002 Kasher prize (best undergraduate project)
- 2001 Humanities and Arts Department award

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- Institute of Electrical and Electronic Engineers (IEEE)

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- Fall 2004 Auditory and Visual Systems
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