Supercomputing and Computational Anatomy

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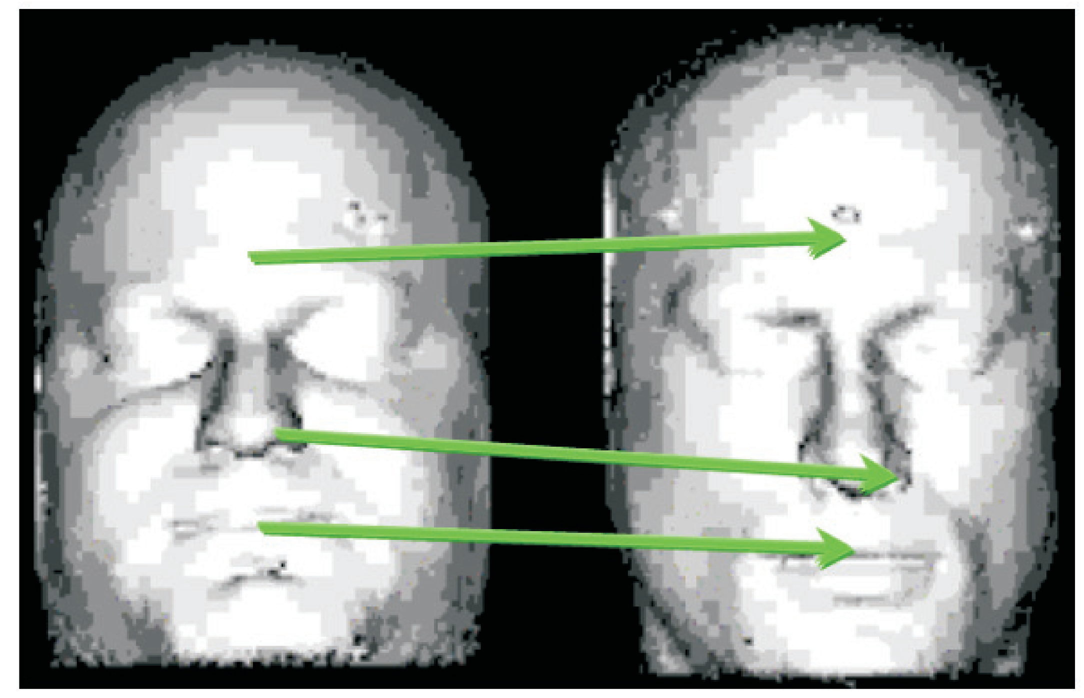
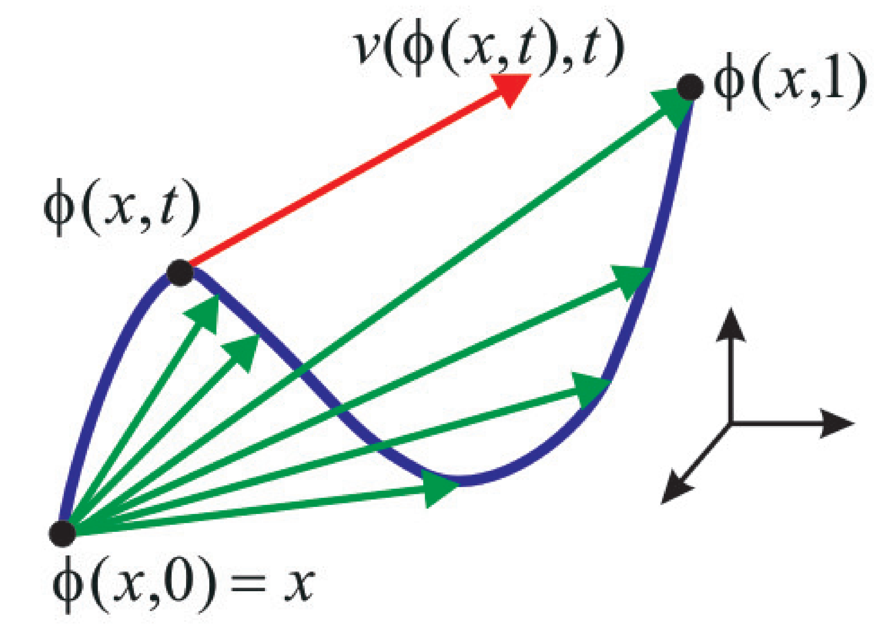
NPACI

The emerging discipline of Computational Anatomy was first announced at the "50 years of Applied Mathematics at Brown University" meeting (Grenander and Miller, 1998). A major application of Computational Anatomy is the analysis of brain images leading to better understanding of neuropsychiatric diseases such as schizophrenia, epilepsy and Alzheimer's (Csernansky et al., 1998). Computational anatomy analyzes metrics on diffeomorphic (invertible) mappings from I_0 to I_1. Associated with the diffeomorphic map ϕ, and a self-adjoint operator L, is the velocity v, satisfying the following optimization problem.





$$\frac{d\phi(x,t)}{dt} = v(\phi(x,t),t) \qquad \phi(x,0) = x$$

$$\frac{d\phi^{-1}(x,t)}{dt} = -\nabla\phi^{-1}(x,t)v(x,t) \qquad \phi^{-1}(x,0) = x$$

The Computational Anatomy Optimization Problem

Exact Matching $\inf_{v\in H}\|Lv\|^2$ **such that** $I_o \circ \phi^{-1} = I_1$

Inexact Matching $\inf_{v\in H}\|Lv\|^2 + \|I_o \circ \phi^{-1} - I_1\|$

The Euler-Lagrange Equations of Computational Anatomy

$$\frac{\partial}{\partial t}(Lv(t))^t + (\nabla^t . v(t))(Lv(t))^t + (v(t).\nabla^t)(Lv(t))^t + (Lv(t))^t\nabla^t v(t) = 0$$

$$(Lv(1))^t + (I_0 \circ \phi^{-1}(1) - I_1)\nabla^t I_0 \circ \phi^{-1}(1)\nabla^t\phi^{-1}(1) = 0$$

The Euler-Lagrange equations are derived from the optimization problem and can be classified as Euler-Poincaré equations (Marsden). Exact matching in 1D leads to Burger's equation (Mumford), and in 3D, with ϕ belonging to the group of volume preserving diffeomorphims, leads to the Euler equations for inviscid incompressible fluid (Arnol'd). This suggests that solving the Euler-Lagrange equations will be similar to solving the 3D Navier-Stokes equations for incompressible fluid on supercomputers such as the IBM RS6000/SP.

Building the Computational Infrastructure for Tomorrow's Scientific Discovery

The Center for Imaging Science is a member of the National Partnership for Advanced Computational Infrastructure (NPACI) based at San Diego Supercomputer Center (SDSC) in the University of California at San Diego. CIS has acquired a 4 node (32 processors) IBM RS6000/SP with a top rating of 100 Gigaflops. Larger jobs will be done on NPACI's 128 node (1000+ processors) IBM RS6000/SP which has performance rating of 1 Teraflop (http://www.npaci.edu).

Brain images contain enormous data that need to be transferred between NPACI partners via the vBNS network at high speeds of 45 Mbps. To facilitate this, the SDSC Storage Resource Broker will be used to access data stored in a relational database on multiple machines.