Research Notes

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February 21, 2008

1 Introduction

We have generated two basic ideas for using the adjoint current as a means to optimizing placement of interstitial brachytherapy seeds. The first idea builds on the Greedy heuristic by Yoo et al. The main questions has been, "how best do we adjust the Greedy output?" Perhaps, that answer is to "nudge" via some displacement vector based on the magnitude of total current at a given seed position.

(This method is decidely not a general optimization problem in that there is no objective function)

In essence, if the Greedy is to be used as a starting point, all of this amounts to a "refinement" to the method.

A second prospective to consider (which has been the focus) is to use adjoint-driven objective function; however, the issue of maintaining dose consraints would have to be considered carefully.

2 "The Nudge"

Assume an initial placement via the Greedy Heuristic; in 2-D, this will probably be a scheme developed by me (as I have only 3-D Greedy code).

We have defined before a so-called "pressure" on a seed placed within the treatment domain, or:

$$\bar{P}_j = w_U \bar{U}_j + w_R \bar{R}_j + w_N \bar{N}_j + \sum_{i=1, i \neq j}^{n} w_S \bar{S}_{ij} \quad (1)$$

where w's are a weighting factor, $\bar{U}$, $\bar{R}$, $\bar{N}$, are the adjoint current from the urethra, rectum, and normal tissue at a point j and $\bar{S}_{ij}$ is the forward current of seed i at the location of j.

Now, the goal of "the nudge" is to improve the overall isocurve and diminish "hot spots". The idea [1] is that seeds "push" away from each other much in the manner as like-charges repel.

So that there is a limit to this seed-seed repelling, we employ repulsion from the sensitive tissues, here manifested as the adjoint current.

The ideal solution, we think, will be an arrangement in which the norm of the P-vector, $||\bar{P}||$ is minimized; this is analagous to charged particles reaching a potential equilibrium.

However, we don't aim in this idea to present [1] as a bonafide objective function; rather, a straight forward iteration with the Greedy result as its initial value is desired. In other words, we hope to establish a "pressure-induced" displacement vector for seeds, which, after a relatively few iterations, leads to net $||\bar{P}||$ = small.

In essence, we employ yet another Greedy heuristic, where the "greedy criterion" is now the largest "push." Some questions arise. How can we quantify the magnitude of displacement given some total "push"? While it is hoped a given displacement would in fact lead to decreased $||\bar{P}||$, would it be better to employ a dimishin displacement function as function of the number of iterations?

Perhaps one way to gain insight on how the process might play out would be to lift all placement constraints (i.e. 5 mm treatment grid). Setting an arbitrary [unit distance / unit force] parameter, we could see the likelihood reinstalling those constraints would introduce difficulties.

(A slight variation to the idea would be to define a complete displacement vector and perturb the placement of all seeds) *e.g. that used in Japanese E-M algorithm.

i.e. define displacement, $\bar{T}$, s.t.

$$\bar{T} = \bar{D} \times k(it) \tag{2}$$

where $\bar{P} = [\bar{P}_1 \ldots \bar{P}_n]$, $\bar{T} = [\bar{T}_1 \ldots \bar{T}_n]$, and k is amplification parameter that (possibly) varies with the number of iterations performed.

What must be done now? 1) A realistic input must be created for Dantsys to generate the adjoint current (and flux) data needed. 2) Appropriate routines for reading this data within Matlab must be generated. 3) The normal Greedy heuristic should be found (or implemented for the 2-D problem) 4) After verifying the results from 3, a test implementation of the aforementioned "nudge" idea should occur.