Introduction

This software distribution includes the following:

1) A statistical atlas of spatial distribution of prostate cancer, obtained from radical prostatectomy specimens.
2) Two optimized biopsy plans, one transrectal and one transperineal, which have been estimated after algorithmic analysis as will be described later.

The rationale behind this work has been that random biopsy with 6 or more needle cores, which is currently done in the clinical practice in various forms, does not take into account information about the statistics of spatial distribution of cancer throughout the prostate, which could better inform the biopsy procedure and guide it toward locations that, if sampled jointly, are likely to yield higher rates of detection of prostate cancer.

Samples

158 radical prostatectomy specimens were used to construct an atlas. These specimens were collected in several hospitals, and were further processed at the Center for Prostate Disease research (CPDR), under the direction of Drs. Judd Moul and Leon Sun. The specimens were collected between 1993 and 1998, and had stages T1 or T2 and PSA levels below 15ng/ml. Cancerous tissue was outlined by trained individuals at the CPDR. A detailed description of the specimen processing can be found in [1, 2], which are also included in the software distribution.

Atlas Construction

In order to account for inter-individual variability in shape and size of the prostate, and therefore to normalize spatial locations within the prostate gland, we used well-established methods [3, 5] for image warping and registration (see Figs. 1 and 2). As a result, the 158 specimens were all matched to a single specimen that was used as template; the template is in the image “model.img” of the distribution. This allowed us to calculate the probability of finding cancer at a particular location in the prostate, by dividing the total number of specimens that had cancer in a given location by 158. This atlas is in the atlas_158.img file in the distribution; the value of this image at a given voxel provides the number of specimens that had cancer in that location.
Fig. 1. Schematic demonstration of the proposed method for the optimization of the biopsy strategy. (a) The atlas is constructed from a number of histological images that are spatially normalized to the stereotactic space (the spatial normalization transformations are represented by dotted arrows). (b) Optimal biopsy sites are determined in the stereotactic space, as indicated by the purple circle, based on the statistics of cancer distribution. (c) The optimal biopsy site is then mapped back to the patient's image space via the transformation $T_{N}^{-1}$.

Fig. 2. An example of the spatial normalization of a prostate subject. (a1) 3D rendering of the model prostate. (a2-a3) 3D renderings of a prostate subject before and after the elastic registration. The white surface denotes the outer capsule of the prostate. (b1) A cross section of the model prostate. (b2-b3) A cross section of the prostate with labeled cancer region before and after the spatial normalization. The labeled cancer regions are denoted as pink regions.
Optimized Biopsy

Also included in the distribution are two optimized biopsy plans. These are actually the most important components of the distribution, as detailed next. The statistical atlas does not actually tell us where one should place a number of needles, so that probability of cancer detection is maximized. Although it would be reasonable to place the first needle in the region where most of the specimens had cancer, it is not clear where the second or third needles should be placed, as one would not want to place all needles in nearby locations. In general, one would like to place the needles in locations that tend to be statistically independent with each other, and therefore don’t replicate each other’s sampling. Solutions to this problem were presented in [1], which were used to determine the optimal needle placement for a given number of needles. Optimal, here, means that the joint placement of a number of needles maximizes the probability that at least one of them will detect cancer. Importantly, practical limitations in exactly accessing a specific spatial location were also taken into consideration, thereby yielding a relatively robust biopsy scheme, with respect to difficulty in accessing a very specific spatial location during a clinical procedure.

Datasets

The dataset includes 4 3D images in Analyze format, each of these corresponds to two files, one with extension “.img” and another one, the header with extension “.hdr”, providing all image information such as sizes, dimensions, resolutions, etc.

Each of the images in the dataset is described below:

- The image **model.img** includes a template prostate, with the prostate region as white and the background region as black.
- The image **atlas_158.img** includes a probability map of statistical prostate cancer distribution, after normalizing all 158 prostate cancer samples to the space of the template prostate.
- The image **model_transperineal_7needle_40x5.img** includes the optimal biopsy locations along transperineal directions.
- The image **model_transrectal_7needle_40x5.img** includes the optimal biopsy locations along transrectal directions.

Prostate Orientation in the Datasets

Fig. 3 below helps the user navigate with respect to the posterior-anterior, left-right, and apical-base directions. They also help visualize, in 3D, the directions of the estimated optimal needle placements. Finally, they provide the estimated expected accuracy of cancer detection, for a different numbers of needles (although only the optimized 7-needle biopsy is included in the distribution). If the user is interested in optimal plans using a different number of needles (e.g. 6 or 8), he/she is encouraged to contact us, as computation of such plans could be performed using SBIA software.

As an example, the region with the highest value of cancer occurrence is on the right. The orientations of the needles also identify the Apex-base, and Posterior-Anterior directions, in the two plans.
Fig. 3. (a) Optimal trans-perineal biopsy and associated detection rates via cross-validation. (b) Optimal trans-rectal biopsy and associated detection rates via cross-validation.

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Disclaimer

The software and data included in this distribution summarize only research results. Application to clinical procedures is entirely a responsibility of the respective clinician. The statistical distributions, and therefore the optimized plans, determined in our study are not guaranteed to be the same in different patient groups, although this patient sample is relatively representative in terms of race and cancer stage. The users are entirely responsible for cross-validating these statistical distributions in their patient populations. The developers of this atlas and SBIA are not responsible in any way for the use of this distribution.


