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A survey of prostate modeling for image analysis

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Computer technology is widely used for multimodal image analysis of the prostate gland. Several techniques have been developed, most of which incorporate *a priori* knowledge extracted from organ features. Knowledge extraction and modeling are multi-step tasks. Here, we review these steps and classify the modeling according to the data analysis methods employed and the features used. We conclude with a survey of some clinical applications where these techniques are employed.

Contents

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1. Introduction

In past few years, much research has been undertaken and many procedures have been developed to assist clinicians in managing prostate cancer. Diagnostic techniques have significantly improved through the combination of prostate-specific antigen (PSA), digital rectal examination (DRE), and biopsies guided by trans-rectal ultrasound (TRUS) or magnetic resonance imaging (MRI).

Currently, the entire prostate gland can be assessed by multi-parametric imaging protocols, particularly those using MRI [1]. Multiparametric MRI, a combination of multiple complementary morphological (T2W) and functional imaging sequences (such as dynamic contrast-enhanced (DCE-MRI), and diffusion-weighted (DWI) and MR spectroscopic imaging (MRSI)), generates a large amount of data. These data require an integrated interpretation to increase the reproducibility, and some authors have also suggested that new standardized reporting tools are needed [2,3].

Semi-automatic or automatic image analysis is essential for managing and treating the large amount of generated data. Currently, one of the important diagnostic challenges for the optimal detection and staging of cancer is developing computer-aided diagnosis (CAD) software based on multimodal and multiparametric images [4,5]. For treatment, the challenges involve developing tools that enable efficient treatment planning, guidance, and monitoring.

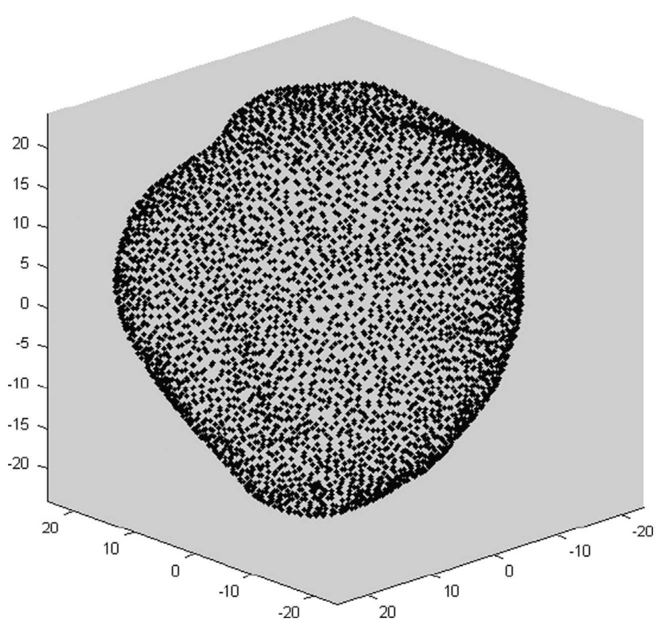

Fig. 1. The point cloud representation of the prostate.

In all these procedures, one of the most important tasks is prostate gland detection and segmentation, which have been the subject of many studies and for which related surveys have been published. Shao et al. [6] presented a survey on the prostate segmentation methodologies developed for TRUS images. In addition, Noble et al. [7] offered a survey on US segmentation methods for different organs (prostate, heart, and breast) and for detecting vascular diseases. Zhu et al. [8] conducted a survey on the computerized techniques developed for prostate cancer detection and staging, including prostate segmentation, prostate staging, computerized visualization and simulation of prostate biopsy, volume estimation and registration between the US and MR modalities. More recently, Ghose et al. [9] classified, reviewed and compared different segmentation methods to provide an overall qualitative estimation of their performance.

However, the prostate is a movable and deformable organ; thus, automatic analysis of prostate images has quickly concentrated on integrating all available information about its properties to guide the algorithms. The accurate integration of these data requires a standardized representation through a modeling process. A typical modeling process consists of the following steps:

- extraction of characteristics and knowledge,
- analysis of characteristics, and
- generation of a model and an atlas.

These steps involve knowledge from different specialties, such as medicine, physics and mathematics. The aim of this paper is to summarize all the techniques used for prostate modeling in a unique document, which will be helpful for this large scientific community. Thus, we review the different types of extracted knowledge (Section 2) and the modeling techniques (Section 3) employed in developing computer technology for prostate image analysis. Section 3 provides a synthetic mathematical description of each technique and the application of these techniques to generate a model. Each part concludes with a brief analysis summary. Section 4 describes the most representative clinical applications where these techniques and models were employed.

2. Extraction of characteristics and knowledge

Accurate modeling of the prostate depends first on the definition of the characteristics that will be analyzed and the database that will be used to extract these characteristics. The anatomy must be defined correctly for any of the considered characteristics. As described by McNeal [10], the prostate gland is divided into four zones: the peripheral zone (PZ), the central zone (CZ), the transition zone (TZ), and the anterior fibro muscular stroma (AFMS). This anatomy could be affected by different parameters, such as the prostate volume, the presence of a tumor, the PSA

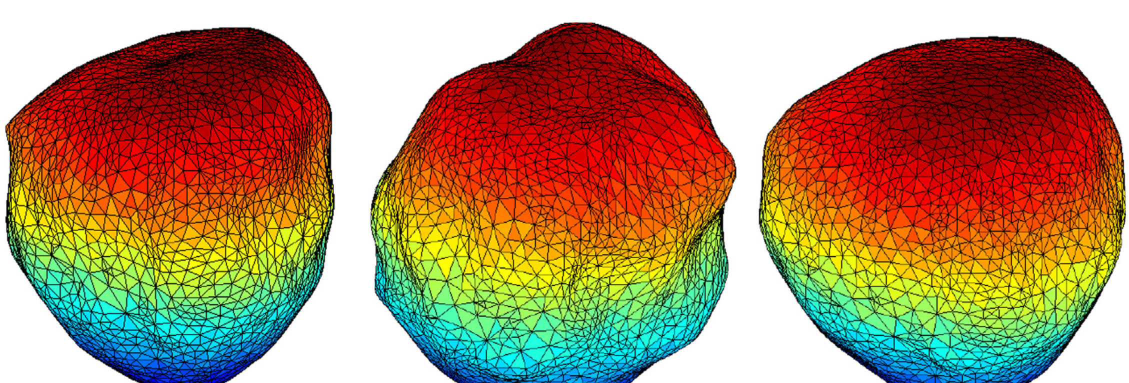

Fig. 2. The triangular mesh representation of different prostate shapes.