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Book Review

Adaptive motion compensation in radiotherapy

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The rapid advances in radiotherapy technology over the last decade, including the widespread implementation of intensity-modulated radiotherapy and volumetric-modulated arc therapy, have transformed the quality of achievable dose distributions. However, converting developments into optimal patient outcomes continue to prove challenging owing to limited success in managing patient and organ movement during radiotherapy delivery. While the gradual introduction of image-guided radiotherapy (IGRT) techniques is making inroads into this problem, it is only with full 4D adaptive compensation for the motion that the benefits of the advances in planning and delivery technology can be fully realised. This book, part of the Imaging in Medical Diagnosis and Therapy series, describes the state of the art in adaptive motion compensation.

The first two chapters present an overview of means of achieving the minimum requirement for a motion-adaptive system, the ability to localise the tumour in real time. Direct methods, which track the tumour itself (such as radiographic imaging) and indirect methods, which use a surrogate for tumour location (such as chest position in lung treatments) are discussed. This is followed by an overview of the theoretical aspects of object detection as applied to the tracking process.

Four methods of introducing adaptation to radiotherapy delivery (gating, the CyberKnife system, tumour tracking with dynamic MLC (dMLC) and tracking with the couch) are considered in the subsequent four chapters. It is disappointing that the two commercially available methods, gating and CyberKnife, are given only superficial coverage in two of the book's shortest chapters, neither serving to be of much practical use to clinics looking to implement the techniques. Tracking with linac MLC or couch are not looked at in much more detail, although the references cited will serve as a useful resource to readers wishing to investigate these possibilities in greater depth.

The most interesting content of this book starts from the seventh chapter. A proposed system for improving the accuracy of beam targeting from the tumour tracking signal is described in detail, although the chapter is definitely one for the mathematically-minded. While the methods are potentially useful in other systems, the chapter is specific to CyberKnife. This is true, too, of the subsequent chapter, which discusses treatment planning implications of adaptive motion compensation, although the generalised concepts of 4D planning and the impact of motion on dose distributions are briefly covered.

A second chapter on treatment planning in the context of motion adaptation follows, this time with reference to dMLC systems. Although nominally about treatment planning, much of the chapter focuses on algorithms used to determine how the treatments are delivered to account for the motion. These are presented in a more readable fashion than the one on the CyberKnife, the mathematics behind the algorithms being saved for appendices. Particularly interesting is the concept of motion-optimized IMRT, in which target and organ at-risk movement is integrated into the inverse planning process rather than relying upon modifying the delivery of a 3D plan, offering potential for impressive reductions in organ at risk doses.

Three further developmental technologies are considered in the following chapters. First, a means of overcoming the additional challenges imposed by the TomoTherapy system's combination of binary collimator and helical delivery is discussed. This is followed by two chapters describing the role of on-treatment MRI in motion adaptation. Its superior temporal resolution and soft tissue imaging with no associated radiation dose compared with CT makes MRI a potentially valuable means of tracking tissue motion. The chapters describe two means of overcoming the main drawback of interaction with a linac's electromagnetic fields, including the use of a gantry-mounted array of cobalt sources rather than a linac.

The increasing complexity of radiotherapy delivery introduces a greater reliance on computerised control systems; the algorithms used in adaptive motion compensation systems take this to a new level. Therefore, the final chapter of the book concerns the need for a robust system for detecting faults in the tracking system and describes one system used for this purpose and to aid quality assurance.

The book has contributions from many eminent scientists and each chapter is well written and informative. The format of a series of essays has its limitations and the book would perhaps have benefited from tighter editing. It would also have been desirable for a little more completeness in places (for example, provision of similar information on treatment planning with gating to that given for CyberKnife and dMLC would enable comparison of the techniques' dosimetric implications). In addition to some inconsistency in the use of terminology, there is noticeable overlap between chapters, many of the later ones starting with often lengthy discussion of basic principles covered earlier in the book when reference to the earlier chapter would be more appropriate. (The chapter on adaptive dMLC treatment planning renders the content of the earlier dMLC chapter essentially superfluous.)

Overall, this is an informative and useful book that will be of particular interest to those seeking an overview of the different means of achieving adaptive motion compensation in radiotherapy that either are or may be available in the near future. While the back cover promises that "readers will gain practical clinical insights into planning and carrying out various types of motion-adaptive radiotherapy treatment", the emphasis is very much on the theoretical and technological aspects. Readers wanting a book focused on the practical application of commercially available systems to patient treatment would be better to consider texts devoted to IGRT and adaptive radiotherapy.

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