



# **Methods on Tumor Recognition and Planning Target Prediction for the Radiotherapy of Cancer**

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zur Erlangung des akademischen Grades

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## Zusammenfassung

Die Strahlentherapie ist neben dem chirurgischen Eingriff und der Chemotherapie eine der drei wichtigsten Methoden zur Krebsbehandlung. Es erfolgt meist eine Bestrahlung des Tumolvolumens aus unterschiedlichen Richtungen mit energiereichen Photonen, die mit Hilfe eines Linearbeschleunigers erzeugt werden. Die Bestrahlungsrichtungen werden so gewählt, daß die Strahlenschädigung kritischer Organe und gesunden Gewebes minimiert wird.

Das wesentliche Anliegen der Dissertation ist es, Methoden vorzuschlagen, um aktuelle Computersysteme zur Planung der Strahlentherapie, weiterzuentwickeln. Diese Methoden wurden als Softwaremodule für ein derartiges Computersystem implementiert.

Das erste Teil der Arbeit betrifft die *Tumorerkennung* in Röntgenbildern. In der medizinischen Praxis werden bei der Strahlentherapie die Tumorgrenzen üblicherweise visuell vom Arzt erfaßt und manuell markiert. Das entwickelte Modul zur Tumorerkennung stellt ein halbautomatisches Werkzeug zur Objekterkennung und -extraktion dar mit deutlichen Vorteilen bezüglich Genauigkeit und Geschwindigkeit. Weiterhin können die eingeführten *Optimalen Merkmalsfunktionen* für die Gebiete des maschinellen Sehens und der Mustererkennung verallgemeinert werden.

Der zweite Teil zur *Tumormodellierung* stellt einen weiteren Beitrag dar. Bei der Strahlentherapieplanung dient er als ein nützliches Hilfsmittel zur Prädiktion des Tumorwachstums unter Berücksichtigung der zugrundeliegenden biologischen Prozesse sowie der geometrischen Randbedingungen, die sich aus der anatomischen Form des Patienten ergeben. Das verwendete Verfahren zur Approximation einer Sequenz von Oberflächen, bei der die einzelnen Oberflächen durch *tensor product splines* repräsentiert werden, beschreibt das Tumorwachstum sehr synthetisch und effizient und kann auch für die Modellierung anderer wachsender Objekte erweitert werden.

Der dritte Teil zur *Zielvolumenprädiktion* stellt ein weiteres Werkzeug für den Arzt zur Definition des Bestrahlungsvolumens in der conformalen Strahlentherapie dar. Die vorgeschlagene Methode erweitert frühere Polynomansätze durch Nutzung von *B-splines*, deren Koeffizienten durch ein *künstliches neuronales Netz* ermittelt werden. Die derartige Anwendung von *künstlichen neuronalen Netzen* ist nach derzeitigem Wissensstand ein weiterer Beitrag dieser Dissertation.



## Abstract

Radiation therapy is, with surgery and chemotherapy, one of the three main modalities for treatment of patients affected by cancer. This treatment usually consists in irradiating the tumor volume, from different directions, with high energy photon beams generated using a linear accelerator. Beam directions are chosen in such a way that the simultaneous radiation damage to critical organs and healthy tissues is minimized.

The main contribution of this thesis is to propose methods in order to improve the performance of the actual radiotherapy planning systems. These methods have been implemented as *software modules* of an integrated computer system.

The module for *tumor detection* in radiographic images is a first contribution. In the medical centers for radiotherapy usually the tumor borderlines are visually recognized and manually designed by medical doctors. The developed module introduces a semi-automatic tool, supporting the object detection and extraction tasks, with a consequent advantage respect to the level of precision and the required time for the same procedure. Furthermore, the improvements introduced with the proposed *optimal feature functions* can be extended to the general fields of Computer Vision and Pattern Recognition.

The module for *tumor modeling* represents a second contribution. In the radiotherapy planning environment, it introduces a useful tool predicting the tumor growth according to the anatomical conformation of the patient and to the related underlying biological processes. The method of approximation for a sequence of surfaces, using some *tensor product splines*, introduces a very synthetic and efficient description of the tumor growth. This method can be easily extended to the modeling of different evolving objects.

The module for *planning target prediction* is a third contribution of this thesis. It introduces another supporting tool for medical doctors, involving the definition of the irradiation volume for conformal radiotherapy. The proposed method extends a former polynomial approach, using some *B-splines* whose coefficients are defined by an *artificial neural network*. The use of *artificial neural networks* in such a way is, at the best of the actual knowledge, another contribution of this thesis.





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Angelo Zizzari



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*“I was born not knowing and have only had a little time to change that here and there”.*

Richard P. Feynman (1918 – 1988)