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(54) NOVEL METHOD FOR THE PLANNING AND DELIVERY OF RADIATION THERAPY

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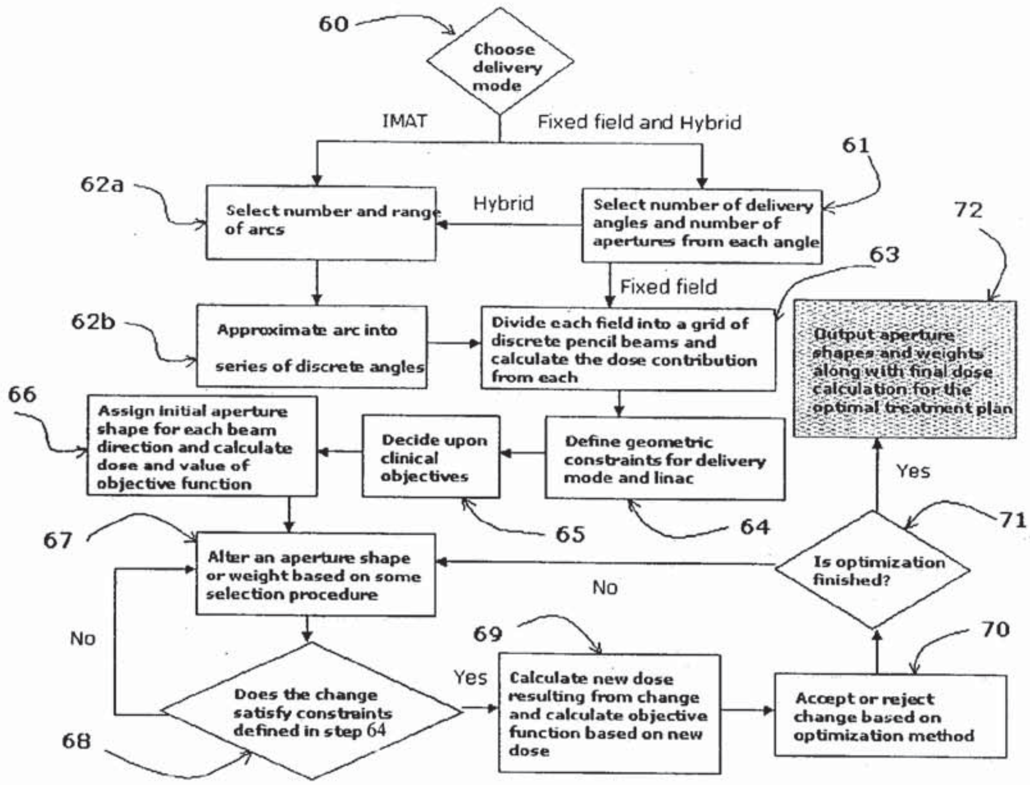
(57) **ABSTRACT**

A new optimization method for generating treatment plans for radiation oncology is described and claimed. This new method works for intensity modulated radiation therapy (IMRT), intensity modulated arc therapy (IMAT), and hybrid IMRT.



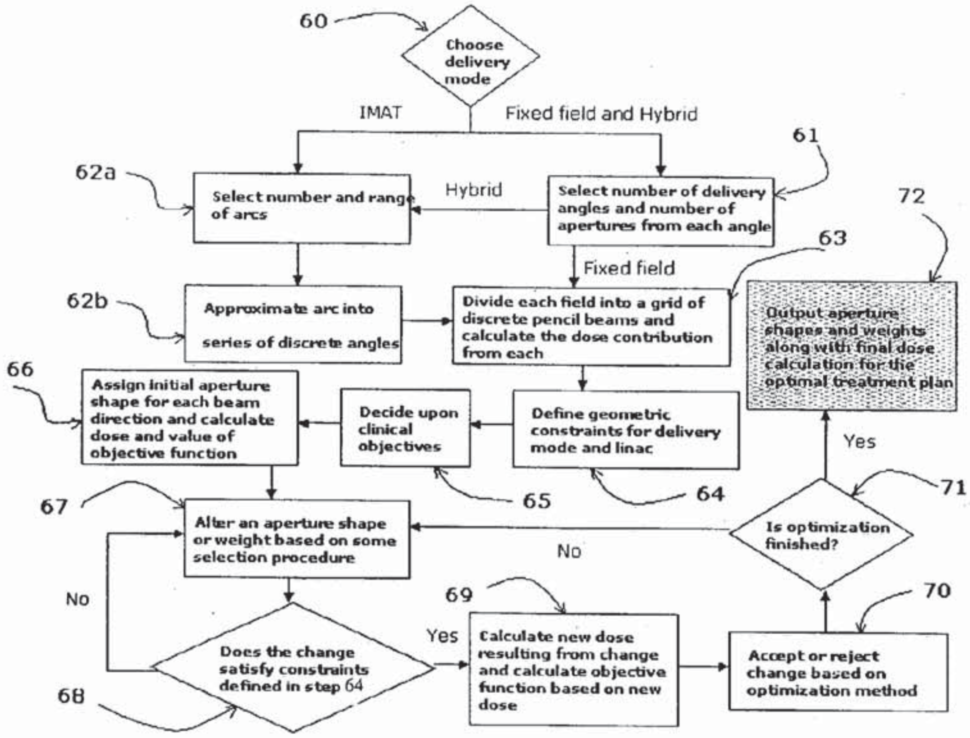


Fig. 1 (NOTE CORRECTION BEING SENT BY FAX)

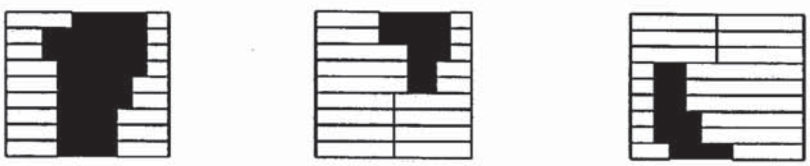


Figure 2

Figure 3

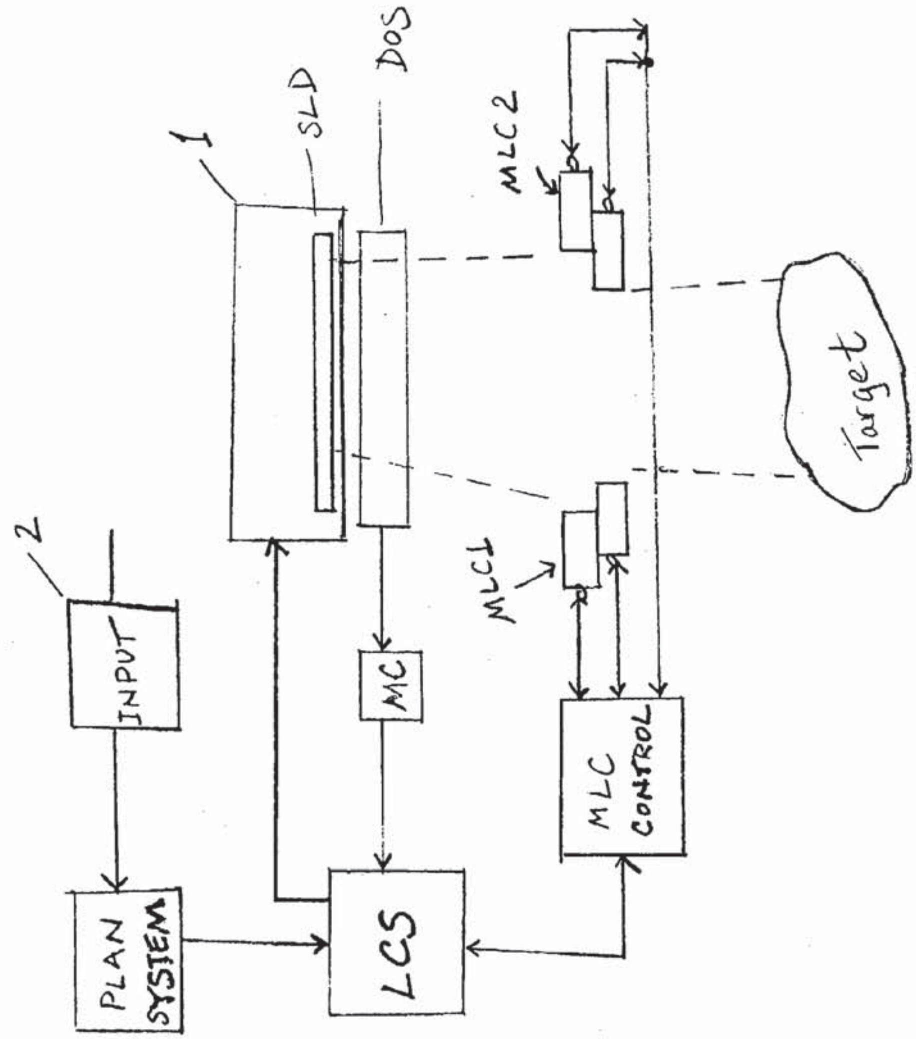

1
SLD
DOS
MLC 2
2
INPUT
MC
MLC1
Target
PLAN SYSTEM
LCS
MLC CONTROL

FIGURE 4

NOVEL METHOD FOR THE PLANNING AND DELIVERY OF RADIATION THERAPY

[0001] This is a non-provisional application claiming domestic priority from Provisional Application No. 60/338,118, filed on Dec. 3, 2001.

[0002] A computer listing of a program according to an exemplary embodiment of the invention is submitted herewith in a CD-ROM as an Appendix to this application. The contents of the CD-ROM are incorporated by reference. The computer program is subject to copyright protection.

[0003] This invention was made with the support of the U.S. government under Grant Number R29CA66075 awarded by NIH. The U.S. government has certain rights in this invention.

BACKGROUND OF THE INVENTION

[0004] 1. Field of the Invention

[0005] The present invention relates to a computerized method for the planning and delivery of radiation therapy. In particular, it is a computerized method that determines the optimal radiation treatment plan for a patient using specified clinical objectives.

[0006] 2. Description of Related Art

[0007] Radiation therapy, in general, is the use of ionizing radiation for the treatment of disease. The most common use is in the treatment of cancer. The goal of radiation therapy for cancer is to destroy any diseased cells while minimizing the damage to healthy tissue. One device for delivering the radiation to a patient is with a linear accelerator, a machine that generates a high-energy beam of radiation that can be controlled and directed onto specified locations. Linear accelerators are sometimes equipped with a multi-leaf collimator (MLC), a device that shapes each individual beam of radiation.

[0008] Prior art treatment planning for conventional cancer radiation treatment is often performed with the aid of three-dimensional patient images acquired using a computed tomography (CT) scanner. Using the three-dimensional patient images, the radiation oncologist pinpoints the location of the tumor and any surrounding sensitive structures. Using the information provided by the radiation oncologist, a treatment planner devises the configuration of radiation beams that will deliver the desired radiation dose to the patient. The parameters that need to be determined by the treatment planner include the beam energies, beam orientations, and field shapes. (Levitt et. al., "Technological Basis for Radiation Therapy: Clinical Applications", 3rd Ed., Lippincott, William & Wilkins (1999)) Using a trial-and-ertor approach, the treatment planner determines an acceptable configuration of the various parameters that meets the clinical goals specified by the radiation oncologist. This approach is called "forward-planning" because a human being determines the parameters that produce the best treatment plan. (Levitt, et. al.)

[0009] Prior art treatment planning uses a "forward-planning" technique for conventional cancer radiation treatment by shaping the radiation field. However, shaping the radiation field alone restricts one's ability to shape the volume of the high radiation dose to conform to the tumor. As a result, adverse complications can arise in the patient being treated because of irradiation of normal structures.

[0010] A recent development in radiation therapy is intensity-modulated radiotherapy (IMRT) in which the intensity of the radiation delivered is modulated within each field delivered. (Webb, "The Physics of Conformal Radiotherapy", Institute of Physics Publishing, Bristol (1997)) The purpose of IMRT is to sculpt the radiation dose distribution so that it maximizes the radiation dose to the tumor while maintaining the radiation dose to normal structures within some pre-specified tolerance. (Webb) In IMRT, highly conformal dose distributions can be achieved through the delivery of optimized non-uniform radiation beam intensities from each beam angle. Successful delivery of IMRT can allow for an escalation of the tumor dose and may enhance local tumor control. The dosimetric advantages of IMRT can also be used to provide a reduced probability of normal tissue complications.

[0011] Because of the complexity of the treatment plans for IMRT, an automated system is required to determine the intensity maps that produce the optimal radiation dose distribution. In contrast to prior art "forward planning" techniques, this approach is termed "inverse-planning" because the automated system determines the parameters that produce the optimal radiation treatment plan. (Webb)

[0012] Currently available IMRT delivery techniques include fixed field beam delivery (IMRT) and intensity modulated arc therapy (IMAT). When radiation is delivered with fixed beam angles, a series of beam shapes are delivered at each beam angle either dynamically, where the leaves of the MLC move during irradiation, or in a step-and-shoot fashion, where the radiation is paused during the movement of MLC leaves. (Convery and Rosenbloom (1992), Bortfeld et al (1994), Yu, Symons et al (1995);Boyer A.L., and Yu C.X.; (1999);) In contrast, IMAT uses multiple overlapping arcs of radiation in order to produce intensity modulation. (Yu, C.X. (1995); Yu et al (2002))

[0013] The complexity of IMRT and IMAT is such that treatment plans cannot be produced through a manual trial and error approach. Instead, one must employ an automated treatment planning system. Furthermore, current automated planning tools are not capable of producing optimized plans for IMAT.

[0014] Current inverse-planning algorithms for IMRT use a two-step approach (Boyer and Yu 1999). In the first step, the portal that defines the radiation beam's eye view (BEV) for each radiation beam angle is divided into a set number of finite-sized pencil beams. The radiation dose for each of these pencil beams is then calculated and the corresponding beam intensities are subsequently optimized subject to pre-specified treatment goals. The second step uses the radiation intensity maps from each beam angle and translates the radiation intensity maps into a set of deliverable aperture shapes. During the optimization of the radiation intensity maps, the delivery constraints imposed by the design of various components of the linear accelerator are not taken into account resulting in treatment plans that are often complex and inefficient to deliver.

[0015] The two step approach used by current inverse-planning algorithms is unable to generate treatment plans for IMAT. With IMAT, the radiation is delivered while the

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