

**Empirical Computation of Absorbed Radiation in
Medium-like Human Body and Graphical
Representation of Dose Distribution.**

By

Tuncay Cemil GÖKÇE

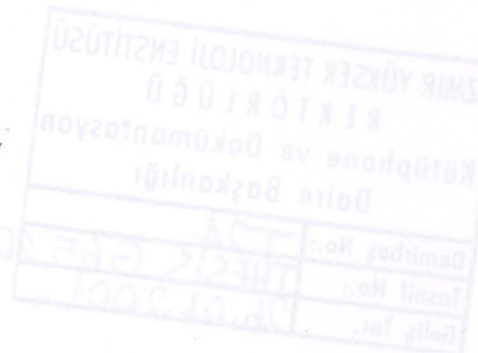
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**Department: Computer Engineering
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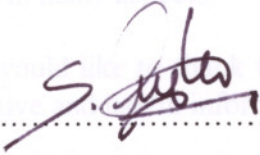
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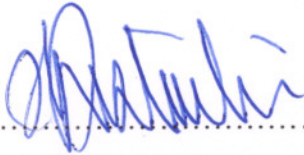


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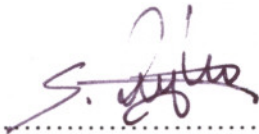


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ABSTRACT

Günümüzde yüksek kapasiteli bilgisayarlar, radyoterapi planlamasında uygun doz dağılımının hesaplanması ve gösterilmesinde yaygın olarak kullanılmaktadır. Bu amaçta ki Computers, in radiotherapy, are now widely used for calculating and displaying dose distributions for optimum therapy planning. There are lots of hardware options and commercial programs, which were developed outside Turkey, available in the market. In this study, we propose a system, which can be used with a conventional PCs running with Windows NT operating system. Our first clinical tests show that this system is very efficient and suitable for clinical requirements. Also in future developments of the software is very easy.

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İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ
REKTÖRLÜĞÜ
Kütüphane ve Dokümantasyon Daire Bşk.

1. INTRODUCTION

The main purpose of this work is to display of radiation dose distribution and modeling in human body and similar medium with experimental calculation method. The main goal of this project is producing an effective and inexpensive Radiotherapy Planning System in cancer treatment. Since the hardware cost effects the price of such planning system, PC compatible computers have great advantage on the overall price.

Ionized radiation has been used for cancer treatment with many forms for 80 years. Malign tumors have more mitoz rate than normal healthy tissues. Therefore, radiation damage is higher than normal tissues at such tumors. The discipline that deals with radiation therapy of cancer is named as "Radiation Oncology" and generally this therapy method is called "Radiotherapy".

Major form of Radiotherapy is external radiotherapy. In this method, ionized radiation is applied to the patient externally with a cobalt-60, x-ray tube or linear accelerator unit.

In order to increase the efficiency of radiotherapy, homogenous and high radiation should be applied to malignant tumor and at the same time lowest dose should be applied to the surrounding healthy tissues as efficient as possible. In order to achieve such dose distribution, various parameters should be planned step by step before the therapy. For this planning procedure, first of all, computer applications had appeared in 1960's. A computerized planning system schedules these sequential steps for a given patient data and therapy machine:

1. Entering 2D or 3D anatomical data of a patient to the program by using a graphic interface.
2. Determination of surrounding tissue and organ contours and homogeneities.
3. Determination of therapy machine and energy.
4. Making different alternative plans by using field sizes, couch and gantry parameters and different filters.
5. Display and printout of the radiation dose distributions (in tumor and surrounding tissues) in the 2D or 3D form by using a graphic interface.

Anatomical contours of the patients can be entered by with the help of scanned Roentgen, CT or MR images. These images are in the form of bitmap images. These images are used as templates of the patient contours. User can use digitizer or mouse to point contour points on the screen. Connected points generate contours. These points are called nodes. These nodes can be added and edited by the user. Also, group operations are supported such as group delete and move.

In this dissertation, the most important calculation algorithms are discussed. The most suitable algorithms have been selected in some calculations.

2. A SHORT DESCRIPTION OF RADIATION THERAPY

2.1. TYPES OF RADIATION THERAPY ON CANCER TREATMENT

High-energy ionizing radiation has been used for treatment of malign diseases and some benign disease [1]. Radiation may be given to the patient mainly in two ways: External radiation or internal radiation (brachytherapy). External beam radiation treatment machines produce ionizing radiation by a radioactive decay of a nuclide or electronically by the acceleration of electron. Up to 1950, most of the external beam radiotherapy was carried up with X-rays generated at voltages up to 300 KVe. After these machines, higher energy machines were developed, example of a these devices are Cs137 and Cobalt-60. Today linear accelerators appeared are being used widely [2].

2.2. RADIOTHERAPY TREATMENT MACHINE TYPES

Basic components of all external beam treatment machines include a radiation source, a collimating system to form and direct a radiation beam, shielding for protection, a control system turn the beam on and off, a light field to delineate visibly the radiation field to be treated, a gantry for rotate the beam, a couch for to support and locate the patient suitable place [1,2], see figure 2.1.

These components are assembled for present day treatment machines in isocentric geometry. The isocenter is a point in space at which the treatment machine rotational axes all intersects [1].

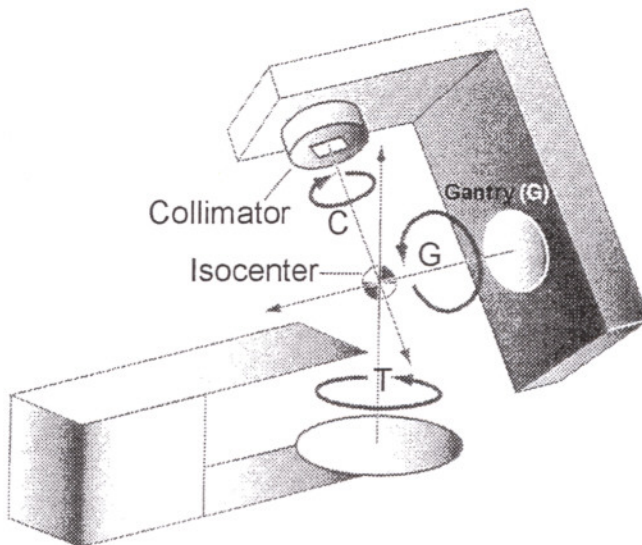


Figure 2.1: A Typical External Beam Treatment Machine

Radiation treatment machines, which use X-ray tube:

These machines are first used as external radiotherapy units. Their energy levels are 50 KV to 300 KV. An X-Ray tube consists of a glass envelope, which has been evacuated to high vacuum. At one end is a cathode (negative electrode) and at the other an anode (positive electrode) [1]. The cathode is a tungsten filament that when heated emits electrons. The anode consists of a thick copper rod at the end of which is placed a small piece of tungsten target. When a high voltage is applied between the anode and cathode, the electrons emitted from the filament are accelerated towards the anode and high velocities before striking the target [2]. The X-rays are produced by the sudden deflection or acceleration of the electron caused by the attractive force of the tungsten nucleus. The X rays are very useful for treatment of the superficial lesions but not suitable to the deep lesions [3].

Radiation treatment machines, which use radioactive nuclides:

These machines use gamma rays, which are emitted from a daughter nucleus formed after radioactive decay of unstable parent nucleus [4]. Ra226, Cs137 and the most commonly Co60 as a source of gamma rays for treatment were pioneered by H.E.Johns and represented a major step in obtaining high energy photons above 1 MeV [3,4]. The source is stored in a shielded head of the machine [1]. The machines have a rotatable gantry, a collimation system and a patient couch like as other external therapy machines [3].

Radiation treatment machines which use linear electron acceleration:

In these machines, electrons are accelerated to high energy and are allowed to exit the machine as an Electron beam or are directed into a target to produce high energy X-rays. Their X-ray energy levels are up to 25 MeV and more useful than Co-60 machines [3], see figure 2.2.

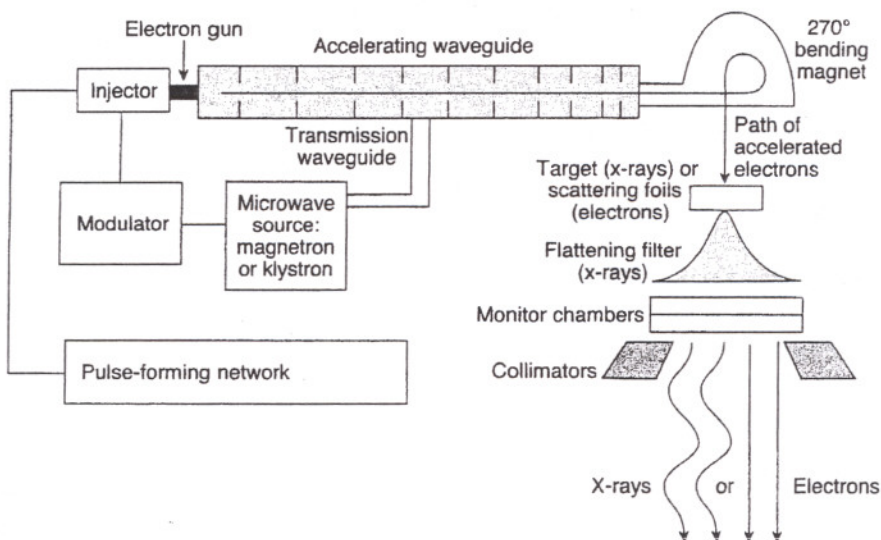


Figure 2.2: Schematic Drawing of a Linear Electron Accelerator.

Major mechanical components are similar to those other external therapy units. A rotatable gantry allows 360-degree rotation of the radiation source at an isocenter to enable multiple beam directions. A set of collimators or jaws provides at least 99.9% attenuation of the primary beam and defines the length and width of rectangular X-ray field. A maximum field size of 40X40 cm at isocenter (generally 80-100 cm) is common with 180-degree rotation of the entire collimator system at isocenter [3]. Collimator pairs can be operated in coupled mode to produce symmetric, rectangular field or in some machines, independently to produce asymmetric fields [2].

Other accelerator techniques have been used to produce a variety of high-energy particles such as electrons, protons, neutrons and higher Z ions. These techniques include the betatron, cyclotron, and microtron. But the uses of those machines are very limited [1].

2.3. THERAPY MACHINE MOTIONS

Different therapy machines use different systems for describing motions and settings. These motions are described in a vendor independent way to simplify entry, display and comprehension of treatment specifications. An international standards body, the International Electrotechnical Commission (IEC), has proposed some conventions [15] but these are not observed by all vendors. The task group reviewed the IEC conventions and found them incomplete for our purposes; moreover, some of their choices were inconvenient. Therefore, a new set of definitions are defined for conventions, using some but not all of the IEC conventions. All treatment beams will be described in the Foundation using these conventions in the same way, rather than using the various machine specific systems.

Linear Motions

The zero positions of linear table motions follow these conventions:

1. Table lateral is zero when the table mid-line lies in a vertical plane that passes through the isocenter.
2. Table vertical is zero when the table surface is at the height of the isocenter.
3. Table longitudinal is zero when the table is at its minimum longitudinal distance from the gantry.

The first two of these conventions follow those defined in [15], pages 15, 17 and 42. The third does not. The third (table longitudinal) reference position presents problems, and is less useful than the other two. This definition is still machine dependent, because the range of motion can be different for different machines. Positive table motions are in the directions of the corresponding coordinate axes in the patient coordinate system:

1. Positive lateral motion is directed to the right (looking from the foot of the treatment table).
2. Positive vertical motion is directed up.
3. Positive longitudinal motion is directed away from the gantry.

The first of these conventions follows the one defined in ref. [12]. The second and third do not. Note that when the table rotation is zero, changes in linear table motions settings are of the same magnitude and opposite sign as the resulting motion of the isocenter within the patient.

Rotations

Rotational motions follow the conventions defined as bellow:

1. Rotations are measured in degrees, using only positive real numbers, beginning with 0.0, up to but not including 360.0 (e.g. 359.0, 359.99 : : : , 0.0, 1.0 : : :) irrespective of movement available.
2. Gantry rotation is zero when the beam central axis is directed vertically downwards.
3. Table rotation is zero when the longitudinal axis of the table is parallel to the axis of gantry rotation.
4. The collimator rotation is zero when, with the gantry angle and turntable angle both set to zero, opening the collimator jaw (or leaf) designated the superior x jaw moves the jaw in the +x direction in the patient coordinate system (thus making the field wider in the +x direction in a transverse plane).

All rotations increase for clockwise rotation when viewed from a point on the axis of the beam between the collimator and the table surface.

Note that the definition of the collimator zero rotation position depends on which of the collimator jaws is designated the superior x jaw. There are typically four collimator jaws, and the identification of the superior x jaw (etc.) is made by each site, not by the therapy machine vendor. Where choice permits, it is usually most convenient to make the definitions such that the collimator zero rotation position is near the center of its mechanical range of rotation.

Wedges and Blocks

Any wedge or block(s) move with the collimator, i.e. are fixed in the collimator coordinate system. Wedge rotation angles are defined in the collimator coordinate system (for the four possible orientations) as follows:

1. 0-degrees, the thin part of wedge pointing along positive y-axis.
2. 90-degrees, the thin part of wedge pointing along positive x-axis.
3. 180-degrees, the thin part of wedge pointing along negative y-axis.
4. 270-degrees, the thin part of wedge pointing along negative x-axis.

Collimators

All collimator jaw or leaf locations and settings are described by x and y coordinates in centimeters in the collimator coordinate system, projected (using a perspective model) to the location of the isocenter. In other words, a 10x10 field is 10 cm wide at the isocenter, while the actual space between the physical collimator jaws is smaller.

Most collimation systems are composed of two pairs of jaws or a larger number of pairs of leaves. The x pairs move in the collimator x direction and the y pair's move in the collimator y direction. In conventionally collimated systems, there is one x jaw pair and

one y jaw pair. In multileaf collimator systems there are a number of leaf pairs in either the x or y direction, but none in the other direction. Motion of a jaw or leaf toward or past the central axis is called closing or extension and motion of the jaw or leaf away from the central axis (to make the field larger) is called opening or retraction.

Within each pair, the superior jaw or leaf is in the positive half plane when it is open or retracted. The inferior jaw or leaf opens into the negative half plane. Thus, to create the obligatory 10×10 field the inferior and superior jaw positions are -5.0 and 5.0 , respectively.

There are typically four collimator jaws, and the identification of the superior x jaw (etc.) is made by each site, not by the therapy machine vendor. Note that the designation of which jaws (leaves) are x and y and which are superior and inferior depends also on the (site specific) choice of which collimator rotation angle is taken to be zero. It is usually most convenient to choose all of these definitions such that the collimator zero rotation position is near the center of its mechanical range of rotation.

In systems which provide over centering in which a jaw or leaf may cross over the beam central axis toward the opposite side, the maximum extension of a superior jaw or leaf past the central axis will be a negative number, and the maximum retraction away from the central axis will be a positive number. However, the maximum extension of an inferior jaw or leaf will be a positive number and its maximum retraction will be a negative number.

2.4. TODAY APPLICATIONS AND THE AIM OF THIS WORK

With the improvement in imaging techniques and facilities available to clinicians, accurate delineation of the malignant tumor extent becomes ever more certain. Coupled with this is a move to conformal types of treatment to maximize the tumor control / complication ratio [1].

This, together with the better understanding of tumor cell characteristics, places increasing importance upon the accuracy with which treatment plan are calculated. In addition treatment machines and accessories, which realize this plan, are important.

Advances in computing technology allow ever-greater complexity of calculation.

3D calculation algorithms and more sophisticated radiotherapy treatment machines will bring more benefit to the increasing numbers of patients [3].

These technologies are very expensive and all of them have been imported from western countries to Turkey.

In this work a planning system has been created firstly in Turkey.

Planning algorithms and necessities are growing and different forms are needed. If our clinics will use a system, which is created in Turkey, they buy such systems more economically and suitable to their requirements.

2.5. OPERATING SYSTEM AND PROGRAMMING LANGUAGE SELECTION

Microsoft© Windows NT operating system is a multitasking environment. It can run many processes at the same time. Windowing features are very useful for this application. This application requires many graphical features. Such as pointing device support, hardware accelerated graphics systems, laser printers, color inkjet printers, digitizers, scanners and many other features are easily handled by this operating system.

Also, This operating system has very good security options. User's rights can be managed easily. User can not access operating system and critic files if Administrator of the operating system sets permissions accordingly.

Microsoft Visual C++ is a very powerful and robust object oriented C compiler. It has many features to write easy and effective code for MS Windows NT. It can handle almost every possible feature.

The Curie Planning system is intended to be portable to any platform that conforms to the specifications defined in ANSI-C and MFC. While effort has been made to produce system independent code, some vendor specific code is unavoidable.

3. A RADIOTHERAPY PLANNING PHYSICAL BASICS

3.1. BEAM DEFINITION AND BEAM MODIFIERS

Photon beams used in radiation therapy have dose characteristics that vary primarily as a function of beam energy and treatment machine design [2]. Main three mathematical functions are used to describe the dose characteristics for external radiation beams, percent depth dose (PDD), tissue-air-ratio (TAR) and tissue-phantom ratio (TPR).

Percent Depth Dose:

PDD is the ratio of the dose at depth, D_d , to the maximum dose, D_m , measured along the central axis of the beam and expressed as a percent [3].

PDD is dependent on the depth, reference depth, maximum dose point, beam quality (or energy), source to surface distances and field size at the surface.

PDD is used for both photon and electron beams and is often in tabular form of dose calculations [2].

Tissue-air Ratio (TAR):

Given a fixed irradiation point in space, the ratio of the dose in phantom, to the dose in air, at some point is called the TAR. TAR indicates how the dose in the air is affected when the air is replaced by the tissue [1]. TAR independent of SSD. TAR is used for photon beams only.

Tissue-phantom Ratio:

TPR must be used for photon energies above about 4 MV, when the air measurements are impractical. As with PDD and the TAR, the TPR is the ratio of two doses, however, both doses are made in phantom (tissue equivalent medium). TPR is the ratio of dose at d depth to dose at reference depth [2].

When reference depth is the maximum dose depth, the TPR is called as TMR. TPR and TMR independent of SSD.

The Scatter Air Ratio.

Mayneord first proposed that PDD could be separated into primary and secondary (or scatter) components. Later Clarkson proposed sector integration of scatter components in calculating the PDD at any point inside or outside an irregular shaped field [5]. This concept was later adapted by Gupta and Cunningham to the TAR.

The concept states that dose at a point are the sum of primary and scatter components. Primary dose is due to photons that have interactions at the point of interest. Secondary dose is due to photons and electrons that scatter to the point of interest from other interaction point [3].

With this concept TAR is given by

$$\text{TAR} = \text{TAR}_0 + \text{SAR} \quad (3,1)$$

Where TAR_0 is the TAR for zero fields, representing primary dose and SAR is the scatter-air-ratio, representing secondary dose [1].

The TAR_0 is found by extra polation of circular field size. The SAR is calculated as the difference between the TAR and TAR_0 .

For an irregular field, an effective TAR can be found that is the sum of the TAR_0 and effective SAR for the irregular field.

The irregular field SAR is found by sector integration [2].

Similar manner, separation of primary and secondary dose can be applied to any of the dose functions in a similar function, for instance, the TMR can be represented as

$$\text{TMR} = \text{TMR}_0 + \text{SMR} \quad (3,2)$$

The methods (dependent on TAR or TMR) are commonly used than PDD, because of independent of SSD [4].

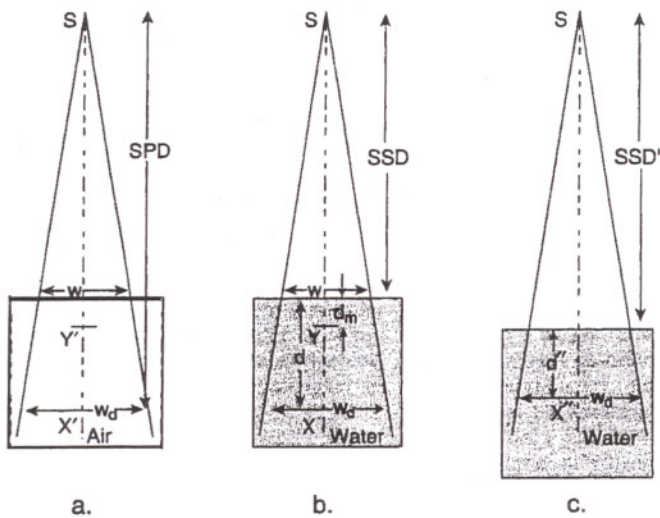


Figure 3.1: PDD, TAR and TPR Measurement Setups.

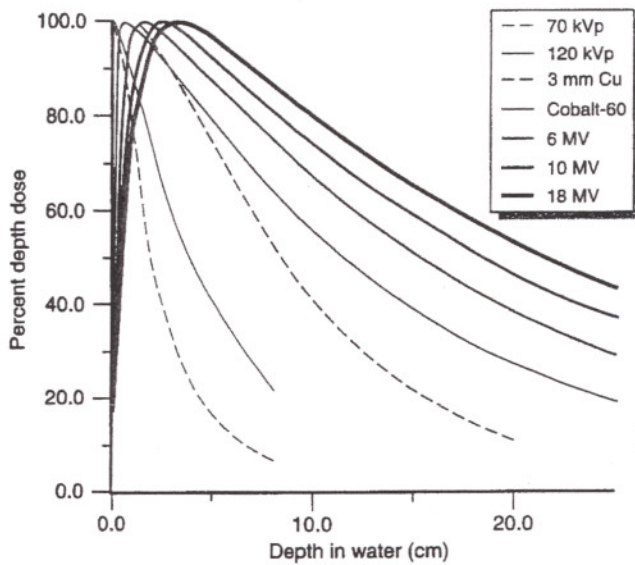


Figure 3.2: PDD vs. Depth graph for different types of photon beams.

Effects of Energy for Photon Beams:

- PDD increases as the energy increases.
- Surface dose decreases as the energy increases.
- HVL (half value layer), measured in lead, increases as the energy increases [3].

Effects of Field Size:

- PDD increases as the field size increases [2].
- Surface dose increases as the field is increased because the amount of scattered radiation.
- Absolute dose rate (or beam out) increases as field size increases [1].

Beam Modifiers:

Various devices can be put into a photon beam to modify the shape of the beam and dose distribution [2]. Collimators and custom blocks are used to shape field, as previously discussed. Wedges produce skewed isodose lines at fixed angles across the central ray [4].

Physical wedge filters made of steel or lead. An alternative wedging system uses no physical filters and produces angled isodose lines by scanning one of the collimator jaws.

Compensators attenuate the beam in desired location to provide dosimetric shaping [5]. Custom made blocks, multileaf collimators and intensity modulation also available methods [1].

Electron Beam Characteristics:

Electrons differ from photons in that electrons have a finite range - travel a certain distance and then stop - their kinetic energy is zero [2].

PPD, field size, flatness and symmetry and sharpness of the beam edge for electrons can be measured similarly as for photon beams [3].

- Effect of energy.
- PDD increases as energy increases.
- Surface dose is high, in the %70-90 range and increases as energy increases.
- The steepness of the dose fall-off region lessens with increasing energy [1].

- Effect of the field size.
- PDD increase only slightly as the field size is increased.
- Surface dose increases slightly as the field size is increased.
- Absolute dose rate increases as the field size is increased [2].

Isodose Distribution:

The PDD, TAR or TPR by itself is not sufficient to characterize a radiation beam that produces a dose distribution in a three dimensional volume (such as human body) [2]. In order to represent volumetric or planar variation in absorbed dose, distributions are depicted by means of isodose curves, which are lines passing through points of equal dose [1]. The curves are usually drawn at regular intervals of absorbed dose and expressed as a percentage of the dose at a reference point.

Thus the isodose curves represent levels of the absorbed dose in the same manner that isotherms are used for heat and isobars for pressure.

Isodose Chart:

Isodose chart for a given beam consists of a family of isodose curves usually drawn at equal increments of PDD, representing variation in dose as a function of depth and transverse distance from the central axis of the beam [3], see figure 3.3.

The depth dose values of the curves are normalized either at the point of maximum dose on the central axis or at a fixed distance along the central axis in the irradiated medium.

The charts in the first category are applicable when the patients are treated at a constant SSD (Source to Surface Distance) [6]. In the second category, the isodose curves are normalized at a certain depth beyond the depth of maximum dose, corresponding to the axis of rotation of an isocentric therapy unit.

This type of representation is especially useful in rotation therapy but can also be used for stationary isocentric treatments.

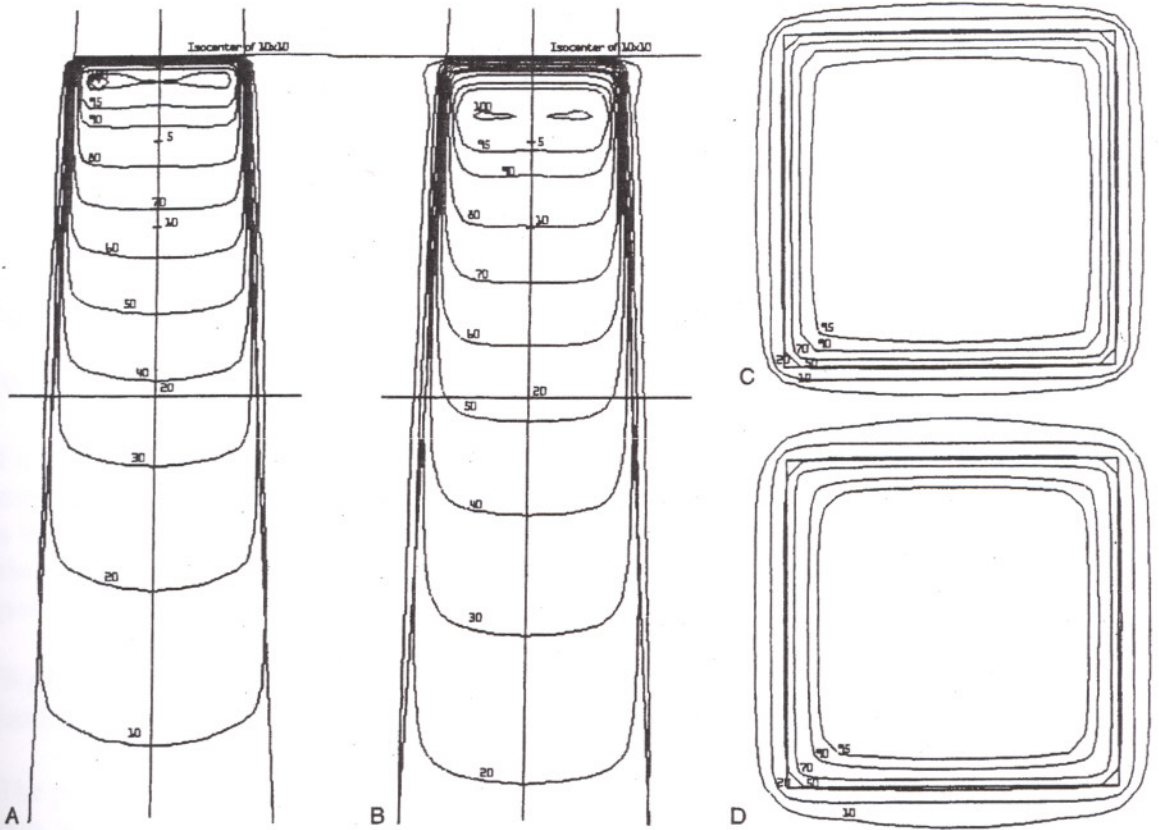


Figure 3.3: A 6MV photon beam cross plain isodose chart, B 18MeV photon beam cross plain isodose chart, C 6 MV photon beam orthogonal plain isodose chart, D 18 MV photon beam orthogonal plain isodose chart.

Examination of isodose charts reveals some general properties of X rays and sometimes electrons.

1. The dose at any depth is greatest on the central axis.
2. Near the edges of the beam (the penumbra region), the dose rate decreases rapidly as a function of lateral distance from the beam axis.
3. Near the beam edge, falloff of the beam is caused not only by the geometric penumbra side scatter.
4. Outside the geometric limits of the beam and penumbra, the dose variation is the result of side scatter from the field and both leakage and scatter from the collimator system [6].

Such a representation of the beam is known as the beam profile. It may be noted that the field size is defined as the lateral distance between the %50 isodose lines at a reference depth .

Measurement of Isodose Curves:

Isodose charts can be measured by means of ion chambers, solid-state detectors or radiographic films. Of these, the ion chamber is the most reliable method, mainly because of its, relatively flat energy response and precision [1,4,12].

Although any of the phantoms may be used for isodose measurements, water is the medium of choice for ionometric measurements. Also automatic devices for measuring isodose curves or dose profiles have been developed for rapid mapping [6].

Wedge Filters Characteristics:

Frequently, special filters or absorbing blocks are placed in the path of a beam to modify its isodose distribution [1]. The most commonly used beam modifying device is a wedge filter. This is a wedge-shaped absorber, which causes a progressive decrease in the intensity across the beam, resulting in a tilt of the isodose curves from the normal positions [6].

Wedge isodose angle (or simple wedge angle) refers to “the angle through which an isodose curve is tilted at the central ray of a beam specified depth” [4], see figure 3.4.

The presence of a wedge filter decreases the output of the machine, which must be taken into account in treatment time calculations. This effect is characterized by the wedge transmission factor (or simply wedge factor), defined as the ratio of doses with and without the wedge, at a point in phantom along the central axis of the beam [3].

Wedge Systems:

Wedge filters are of two main types. The first may be called the individualized wedge system, which requires a separate wedge for each beam width, optimally designed to minimize loss of beam output [3]. The second system uses a universal wedge, i.e., a single wedge serves for all beam widths.

Effect on Beam Quality:

In general, the wedge filter alters the beam quality by preferentially attenuating the lower-energy photons (beam hardening) and to lesser extent, by Compton scattering that results in energy degradation (beam softening).

Although the wedge filters produce some change in beam quality, as noted above, the effect is not large enough to alter other calculation parameters such as the PDD, TAR or TMR.

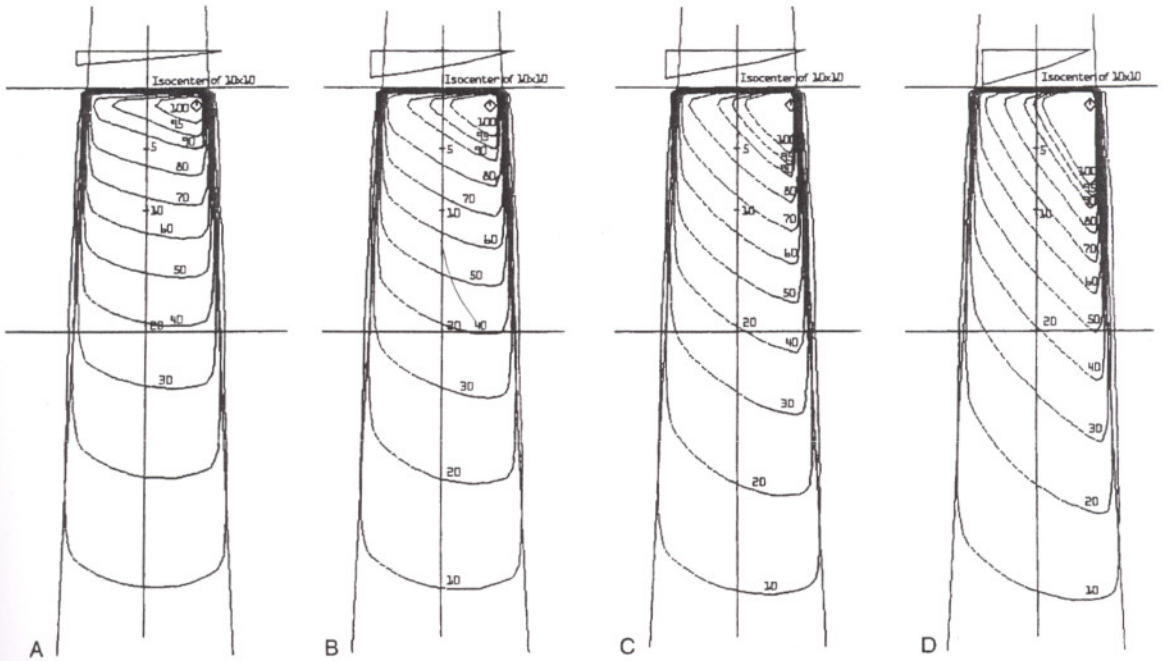


Figure 3.4: Isodose curves with physical wedges. A: 15° , B: 30° , C: 45° and D: 60°

3.2. BASIC GEOMETRIES

Irradiation geometries for dosimetric measurements are drawn, figure 3.5. Main parts consists

- 1- Radiation source
- 2- Radiation field: A rectangle, which created by collimator.
- 3- Surface: Body or body equivalent material surface
- 4- Central Ray: It also named as a central axis.

Therapy machine geometry will be explained in the section 4.6 in detail.

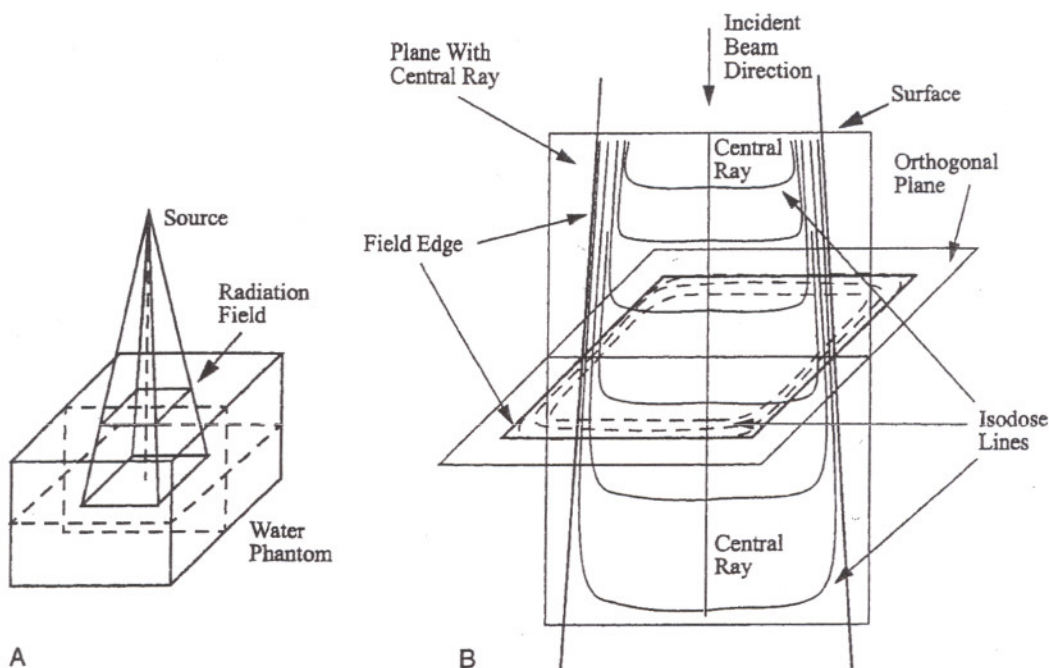


Figure 3.5: Irradiation geometries for dose measurements. A: Beam orientation with phantom. B: Plains orthogonal to the central axis and isodose curves.

3.3. EXTERNAL BEAM TREATMENT MAIN PURPOSE AND PROCEDURES

The procedures of radiation therapy consist of a number of steps, one of which is conventional or computer-aided simulation and there after calculation and visualization of the radiation dose pattern that will result of radiation beams is applied to a patient. All of procedures named as treatment planning [1].

During treatment planning different beam combinations are investigated. Usually the beams are simulated are fine-tuned the beam weights might be adjusted, wedges added, different type and energy beam might be used, field size adjusted, different normalizations used and compensation checked. The main intent is to produce a treatment plan in the form of an isodose distribution through one or many transverse or other planes that can be evaluated by the physician and approved or modified Treatment plan describe the following characteristics about the patient's treatment [4].

1. Prescription isodose or depth (i.e., the %97 line or at 3 cm deep) - gives the location where the prescribed dose is to be given.
2. Definition of interest relating to treatment volumes.
3. Beam weighs-the relative dose delivered to the prescription or normalization point by each beam.
4. Presence of beam modifiers (wedge, custom block, compensation filters)
5. Size and shape of each field (collimator settings)
6. SSD of each field.
7. Presence of "in homogeneities" - volumes that are not water / soft tissue equivalent for which dose might need to be corrected (lung, bone, metal prosthesis)
8. Number of monitor units or amount of exposure time that must be set on the machine for each beam.

Dose Specification:

Components of dose prescription for a patient treatment course include the patient's name, clinic protocol number, treatment site, radiation beam type and energy (photons electrons), prescription point location, dose Per fraction, number of fractions and total dose. The point of prescription defines the location with in the patient body where dose is to be delivered and, thus, defines the geometric point for dose computation. Prescription point selection and additional recommendations for prescribing, recording and reporting volumes of interest are specified by ICRU 50 [4].

ICRU 50 defines five volumes of interest relating to treatment. The definitions are the following:

- Gross tumor volume (GTV): GTV is the volume that contains the gross palpable or visible extent and location of malignant growth. GTV may be identified on a simple contour, a radiograph or sectional images.
- Clinical target volume (CTV): CVT is the volume that contains the GTV and any suspected microscopic disease. The CVT is the volume that must receive the prescribed dose to effect cure or palliation.
- Planning target volume (PTV): PTV is a volume that contains the GTV and CTV that is defined to account for the irradiation geometry and all uncertainties in treatment, such as organ and patient motions and set-up errors.
- Treated volume (TV): The TV is the volume enclosed by a selected (prescribed) isodose surface and is function of the treatment geometry required for planning the PTV. For an acceptable plan the TV will be greater than the PTV although an ideal TV: PTV ratio would be 1,0, indicating perfect conformation (assuming the locations of the volumes were identical).
- Irradiated volume (IV): The IV is a volume that receives a "significant" dose, where the significance is determined by morbidity or other measures.

Dose Recording and Reporting Rules The ICRU recommendations for dose include a point for dose computation and indicators of dose homogeneity. The Reference point is a point with in the PTV at which dose is specified. The criteria for selecting the Reference point are that.

The dose at the point is clinically relevant and representative of dose in PTV.

- The point is easily defined by anatomy or geometry.
- The dose gradient at the point is of steep.

With these criteria, suitable point locations include the center of PTV, near the central axis, or where tumor cell density is a maximum. In many cases, the isocenter has these characteristics and serves as the Reference Point.

Dose homogeneity is also to be reported and is represented as isodose line, (2D, 3D or surfaces) and maximum and minimum doses in the PTV.

Together, the reference, maximum, and the minimum point doses represent the dose to the PTV as, well as the variation in that dose.

Dose Reporting for Different Techniques: ICRU 50 demonstrates its recommendations for three levels of complexity, single plane plans, multiple planes, and 3Dvolume studies. In each case the Reference Point dose is computed and the maximum and minimum point doses are estimated or computed. Isodose distribution is computed if a contour plane or multiple planes are acquired.

Beam Nomenclature

When using a complex field arrangement it can be difficult to describe beam orientation. Generally, a system has been developed to allow this description to be simply done. Simple beams are named their anatomic positions. Examples include AP, PA, Right lateral, left lateral. For more complex beams a coordinate system may be used [3].

Importance of Planning Procedures: The purpose of treatment planning is 2- fold. One is to predict, as part of the dose planning process, what dose distribution can be achieved with a selected beam arrangements. Another is to record what dose has been given so that post-treatment analysis can be carried out. Both of these are important [2].

The production of radiation dose distributions is this central to treatment planning and must be completed, at least to some extent for every patient. It is a labor-intensive procedure and is appropriate for computer application.

Another step, that is part of treatment planning. Includes choosing the process is frequently referred to as "optimization". It is usually done usually by trial and selection. There has been only limited success in applying computers to this procedure.

The limit as to how high the dose at the target volume may be set by the dose inevitably given to sensitive healthy tissues. Too high a dose may result in serious injury and this would be an unacceptable consequence of the treatment. Prescriptions in radiotherapy are based on the need for this compromise between likelihood of tumor control and induced complications [7,9,10,11,12].

Unfortunately, we have little quantitative information about these curves. In general, we know them only qualitatively, but where they are known, from animal experiments, and a few human situations, they look much like the ones shown.

Note that the quantity being discussed here is the dose delivered to the patient and this includes all the sources of errors involved with machine dose calibrations, dosage calculations, planning the treatment, and carrying it out.

If the desired accuracy of $\pm 5\%$ is to be achieved in the end result, each step must be considered with care and each must involve errors considerably less than the $\pm 5\%$.

Single Fields:

Treatment by a single beam is seldom used except in some cases in which the tumor is superficial [3]. The following criteria of acceptability may be used for a single field treatment:

1. The dose distribution within the tumor volume is reasonably uniform (e.g. within $\pm 5\%$).
2. The maximum dose to the tissues in the beam is not excessive (e.g. Not more than 110 % of the prescribed dose and,
3. Normal critical structures in the beam do not receive doses near or beyond tolerance [3].

For treatment of most tumors, however, a combination of two or more beams is required for an acceptable distribution of dose within the tumor and the surrounding normal tissues. Although radiation fields may be combined in many ways [1].

Parallel Opposed Fields:

The simplest combination of two fields is a pair of fields directed along the same axis from opposite sides of the treatment volume. The advantage of the parallel opposed fields is the simplicity and reproducibility of set up, homogeneous dose to the tumor and fewer chances of geometrical miss (compared with angled beams). A disadvantage is the excessive dose to normal tissues and critical organs above and below the tumor [1,4]. Such an example has been discussed at the Chapter 9 with manual methods.

Multiple Fields:

One of the most important objectives of treatment planning is to deliver maximum dose to the tumor and minimum dose to the surrounding tissues. In addition dose uniformity within the tumor volume and sparing of critical organs are important considerations in judging a plan. Some of the strategies useful in achieving these goals are:

1. Using fields of appropriate size.
2. Increasing the number of fields or portals.
3. Selecting appropriate beam directions.
4. Adjusting beam weights (dose contribution from individual fields).
5. Using appropriate beam energy.
6. Using beam modifiers such as wedges and compensator filters.

Although obtaining a combination of these parameters, which yields an optimal plan, is time consuming if done manually, treatment-planning computers are available. Some of these systems are highly interactive so that the user can almost instantly modify, calculate and examine various plans to select one that is clinically superior [4]. Reduction of dose to subcutaneous tissue and normal tissue surrounding the tumor can be achieved by using a combination of three or more fields. Thus, by using multiple fields, the ratio of the tumor dose to the normal tissue dose is increased [8].

Although multiple fields can provide good distribution, there are some clinical and technical limitations to these methods. For example, certain beam angles are prohibited because of a treatment may be better with parallel opposed than with the multiple angled beam arrangement. It is therefore, important to realign that the acceptability of a

treatment plan depends not only on the dose distribution on paper but also on the practical feasibility, setup accuracy and reproducibility of the treatment technique [1].

Isocentric Techniques:

Most modern machines are constructed so that the source of radiation can rotate about a horizontal axis. The gantry of the machine is capable of rotating through 360 with collimator axis moving in a vertical plane. The isocenter is the point of intersection of the collimator axis and the gantry axis of rotation [1].

The isocentric technique of irradiation consists of placing the isocenter of the machine at a depth within the patient and directing the beams from different directions. The distance of the source from the isocenter, or the SAD, remains constant irrespective of the beam direction. However, the SSD in this case may change, depending on the beam direction and the shape of the patient contour [4]. For any beam direction, the following relationship holds:

$$SSD = SAD - d \quad (3,3)$$

Where d is the depth of the isocenter. The SSD value can be calculated, if the depth and the position of isocenter from one direction are known.

Rotation Therapy:

Rotation therapy is a special case of the isocentric technique in which the beam moves continuously about the patient is the rotated while the beam is held fixed. The technique offers little advantage over the isocentric technique using multiple stationary beams. Especially when intricate blocking is required, rotation therapy should not be attempted [4].

Rotation therapy is best suited for small, deep-seated tumors. Calculating for rotation therapy can be made in the same way as for the stationary isocentric beams, except that a reasonably large number of beams should be positioned around the patient contour at fixed angular intervals [2,3].

Corrections For Contour Irregularities:

Basic reference dose distribution data are obtained under standard conditions, which include homogeneous unit density phantom, perpendicular beam incidence and flat surface. During actual treatment, however, the beam may be obliquely incident with respect to the surface and in addition the surface maybe curved or irregular in shape. Under such conditions, the standard dose distributions can not be applied without proper modifications or corrections [1].

Generally three methods are used to correct contour irregularities: effective SSD Method, TAR Method, Isodose shift method [13].

Corrections for Tissue in Homogeneities:

Application of standard isodose charts and depth dose tables assume homogeneous unit density medium. In a patient, however, the beam may transverse layers of fat, bone, muscle, lung and air. The presence of these in homogeneities will produce changes in the dose distribution, depending on the amount and type of material present and on the quality of radiation.

Generally, three methods of correcting for in homogeneities: TAR Method, Power Law TAR Method, and Equivalent TAR Method [6,7,9,10,11,14,15,16].

Field Shaping:

Shielding of vital organs and tissues within a radiation field is one of the major concerns of radiotherapy. Considerable effort is spent in shaping fields not only to protect critical organs but also to avoid unnecessary irradiation of the surrounding normal tissue.

The shaping of fields is made with shielding blocks or therapy machine with equipped multileaf collimator system and asymmetric jaws and multileaf collimators [1,5,8].

3.4. ACQUISITION OF PATIENT DATA

Accurate patient dosimetry is only possible when sufficiently accurate patient data are available. Such data include body counter, outline, and density of relevant internal structures, location, and the extent of the target volume. Acquisition of these data is necessary whether the dosimetric calculations are performed manually or with a computer. However, this important aspect of treatment planning is often executed poorly [4].

Localization of internal structures for treatment planning should provide quantitative information in regard to the size and location of critical organs or in homogeneities. Although qualitative information can be obtained from diagnostic radiographs or atlases of cross-sectional anatomy, they can not be used directly for precise localization of organ's relative to the external contour. In order for the contour and the internal structure data to be realistic for a given patient, the localization must be obtained under conditions similar to those of the actual treatment position and on a couch similar to the treatment couch [2,3].

Transverse tomography, computed tomography, magnetic resonance imaging, ultrasonograph can be used for the localization of internal structures and the volume [1].

4. MATHEMATICAL BACKGROUND AND EMPIRICAL METHODS

4.1. CALCULATION METHODS

Early methods for treatment planning used isodose charts produced from measurements in water phantoms and modified these according to patient information [2].

It is convenient to consider computerized planning algorithms in this same way, firstly by considering representations of beams incident upon a homogenous phantom.

Secondly by considering correction factors to be applied for patient shape and anatomical detail. Then 3D plans, optimization software, multileaf collimator applications and last intensity modulated radiotherapy applications [2,3].

4.2. TWO-DIMENSIONAL CALCULATION METHODS

A truly two-dimensional algorithm is one, which will calculate the dose distribution only in two dimensions.

Most algorithms are not strictly two-dimensional, in that they allow calculation in other planes parallel to that described above.

Types of 2D planning Algorithms:

1. Fully Measured Beams,
2. Partially Measured Beams,
3. Empirical/Semi-empirical Methods,
4. Semi-physical method.

1. Fully Measured Beams. (Matrix Method):

It is possible to pre-determine each and every possible field arrangement. Which is to be used with in a center, and to "full measure" each field. The finer the matrix, the greater the size of the resultant dataset. Doses at points other than matrix point may be derived by interpolation from surrounding values [6].

Wedge fields must be considered as separate data entries. Any suitable matrix geometry may be used, e.g. a diverging matrix [7,9,10].

For this method, only those field sizes for which data exists may be calculated. No modern computerized planning system uses a fully measured approach.

2. Partially Measured Beam:

The use of interpolation may be extended to reduce the data requirements.

Such interpolation will be rely accurate even for a widely spaced data points when the radiation dose varies slowly and smoothly, but the algorithm geometry must allow closer spacing for rapid variations in dose [10,11].

The dose at any point (x, y) with in the field may be determined.

$$\text{Relative Dose}(x,y) = \text{Depthdose}(y) * \text{Profile}(x,y) \quad (4,1)$$

Depthdose(y) factors and Profile (x, y) factors than non-measured field sizes can be found by means of interpolation.

The model may also be extended to a third dimension with a second profile term, profile (z, y) factor. The model has also been modified to allow variable sparing of fan-lines, allowing concentration with in the edge of the field (penumbral region) [8].

3. Empirical and Semi-empirical Generators

Depth (y) and Profile (x,y) factor may be represented by an empirical methods. For Depth (y), the mathematical formulae must allow for inverse-square variation in air, a TAR factor, and suitable normalization [16].

Similarly, a various generator functions have been suggested for the profile (x, y) factor. The model of sterling generated the profile by a composite of separate functions to fit the in-field, penumbra and outer-field regions [13].

4. Semi-physical Methods

Semi-physical generator is the primary and scatter separation model, as proposed by Cunningham in this model [17].

$$\text{Dose}(x, y) = \text{Primary}(x, y) + \text{Scatter}(x, y) \quad (4,2)$$

Primary (x, y) can be found using field diameter zero (non scatter) TAR and corrections of inverse-square rule and normalizations.

Scatter (x,y) depends not only on depth and field radius, but also on position with in the irregular shape of the field. It may be determined from tabulated values of S (y, r) by scatter integration methods. In all of these models must be used for methods to correct for external shape. There are several techniques are used.

These are: Linear attenuation coefficient method, effective SSD method, Ratio TAR Method. In addition several methods are used for to correct for internal in homogeneities [14,15,17].

These are: Generalized methods (which similar linear attenuation, effective SSD an Ratio TAR) and Power-Law correction method.

Summary and Implantation of the Commercial Systems:

Nowadays, of the various models presented being based up on interpolations of measured data, accurate.

Consideration should be given, however, to situations where such data may not be applicable, i.e., where scatter may be expected to change. For example, to the dose beneath lead blocks, outside rectangular fields or when using irregular field shapes.

The primary/scatter model has also been implemented in a number of systems. It relies on the accuracy by which parameters are fitted to measured data to generate its fields [1,2,3].

Of the correction methods discussed, the power-law method is the most powerful and generally the most accurate. Even with this correction, calculation errors may exceed %5, particularly with in homogeneities of relatively low density, even for patients where the limitations of 2D planning are not otherwise over-restrictive.

4.3. 3D CALCULATION METHODS

The various forms of 3D algorithms differ in their reliance on measured at data. Some models make extensive use of data in the form of look-up tables (depth doses, off-axis ratios, primary ratios), and may be considered as extensions of "partially measured" 2D models. Others are extensions of "semi physical" 2D models and lastly Monte-Carlo based models [1,2,3,4].

Extensions From 2D Models.

1. Off-Center Ratio Models:

In this model;

$$Dose(d,x,y) = D(d) * OCR * MF \quad (4,3)$$

Dose D (d) is the dose at depth d on the central axis, MF is a factor accounting for the presence of beam modifier, (wedge, blocks, compensator), and OCR is a composite off-center factor. The model relies heavily on measured data [3,14].

OCR is a composite off-center factor that takes account of:

- a. Variation in dose with radial distance from the nominal beam central axis, accounting for 'horns' and variation in beam energy (penetration) with radial distance a 'Primary Off-Center Ratio' POOCR [1,4,18].
- b. Variations of dose with respect to position within the beam, accounting for the fall-off of dose at field edges and scatter outside the field a 'Boundary' term BT [1,4,18].

The OCR is a function of depth, field size and position, an a general form it is;

$$OCR(d,x,y,W,H)=POCR(d,r) * BT(d, W-x) * BT(d, H-y) \quad (4,4)$$

where W, H are the field width and height.

2. Scatter Integrations Models.

The dose at any point within a medium may be consisted of primary radiation and scattered radiation, where the latter may be from first scatter, second scatter or multiple-scatter. There are various mathematical and analytical models. The models relies TAR, TPR and SAR, SPR data [5,17].

3. Monte Carlo Calculations.

Monte Carlo Calculations are based upon the generation of random interactions within the medium. As Monte Carlo Calculations are probability based, it is necessary to calculate a large number of individual photon and electron histories in order to achieve levels of accuracy required for treatment planning. Each history requires many calculations to complete. The overall time is there fore excessive, even for today's computers and Monte Carlo techniques are not directly employed in present-day planning systems [3].

4. Convolution / Superposition Models.

The beam spread function or pencil kernel is effectively a two dimensional distribution of dose resulting from the application of a narrow pencil beam. The pencil beam kernel may be derived by Monte Carlo techniques or by the deconvolution of measured beam profiles. Recently differentiated pencil beam kernels derived from these approaches [3,14,15,18].

For use in treatment planning applications, an intensity distribution function $I(x', y')$ (in equation 4,5) within a plane at depth (z) being derived by convolving this intensity distribution with the appropriate beam spread function $K(x, y)$:

$$Dose = D(x', y', d) = \iint I(x', y') \cdot K(x - x', y - y') dx dy \quad (4,5)$$

This integration may be evaluated using Fast-Fourier Transform calculations. The pencil beam kernel may be derived by Monte Carlo techniques, or by the deconvolution of measured beam profiles. [1, 4, 14, 18].

The pencil beam mode has found extensive use in electron beam planning and also to determine the correction factor required in the use of irregular or blocked fields.

4.4. DEFINED AXISES FOR CURIE PLAN

The operations which draw graphic objects (for example beam portals) into views rely on a number of coordinate system transformations. Coordinate systems are defined that describes the principal transformations involved in these operations. The coordinate system definitions used by Curie plan largely agree with those discussed in [17]. Unless otherwise specified, the scale is in centimeters and angular transformation rotations in the positive direction are counterclockwise as seen from the positive axis, looking toward the origin of the coordinate system. Curie plan makes use of the following coordinate systems: treatment room space, gantry space, collimator space, couch space, patient space, view plane space, and screen space. Objects with a graphic extent are defined in one of these coordinate systems, and their coordinates may be transformed between systems for the purposes of graphic display.

4.4.1. TREATMENT ROOM COORDINATE SYSTEM DEFINITIONS

The origin of this space is at the treatment machine isocenter. The x-axis points to the right when the viewer faces the treatment machine gantry protractor, the y-axis points directly up, and the z-axis is the axis of gantry rotation and points directly away from the machine. See figure 4.1.

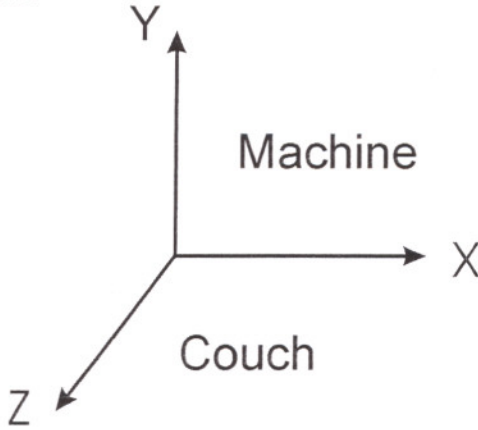


Figure 4.1: The treatment room coordinate space

4.4.2. GANTRY COORDINATE SYSTEM DEFINITIONS

The origin of this space is at the treatment machine isocenter. The x-axis points to the right when facing the treatment machine, the y-axis is the axis of gantry rotation and points directly toward the machine, and the z-axis points directly toward the beam source. The gantry space is obtained from the treatment room space by rotating 90 degrees about the xaxis and then rotating by the gantry angle g around the new y-axis. See figure 4.2.

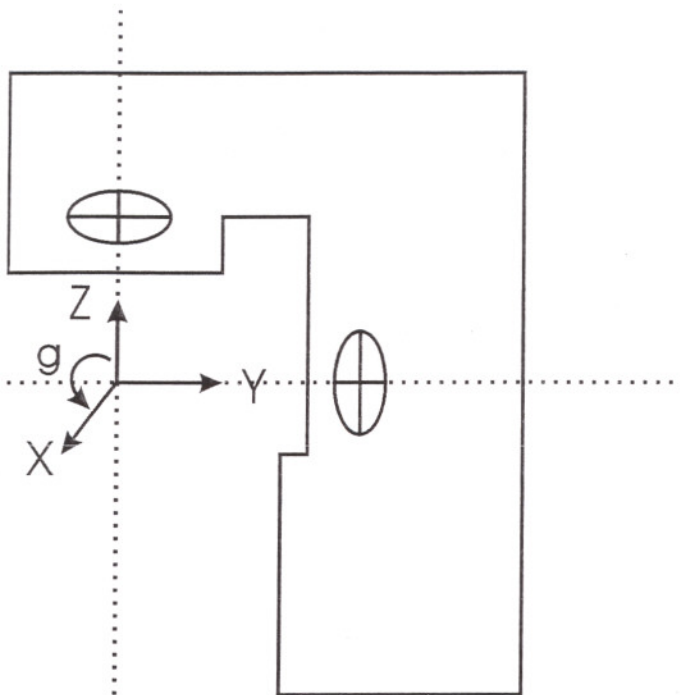


Figure 4.2: The Gantry coordinate space

4.4.3. COLLIMATOR COORDINATE SYSTEM DEFINITIONS

The origin of this space is the treatment machine isocenter. The x-axis and y-axis are rotated from their counterparts in the gantry space by the collimator angle c , and the z-axis points toward the beam source (the apparent source of the radiation beam). See figure 4.3.

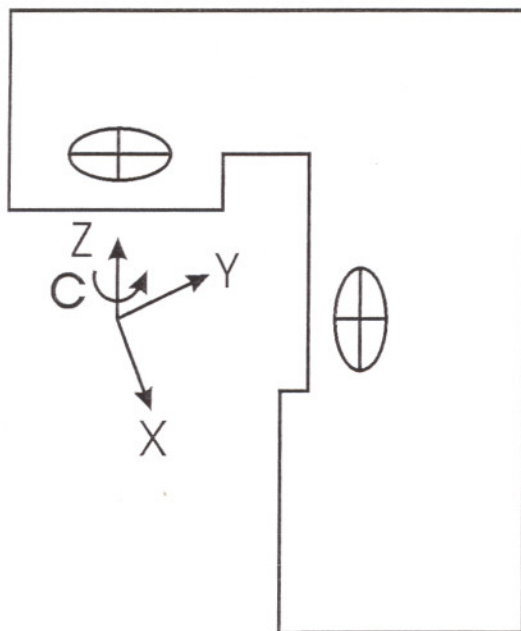


Figure 4.3: The Collimator coordinate Space

4.4.4. COUCH COORDINATE SYSTEM DEFINITIONS

The origin of this space is the treatment machine isocenter. The y-axis points directly up, and the x-axis and z-axis are rotated from their counterparts in the treatment room space by a turntable angle t . See figure 8.

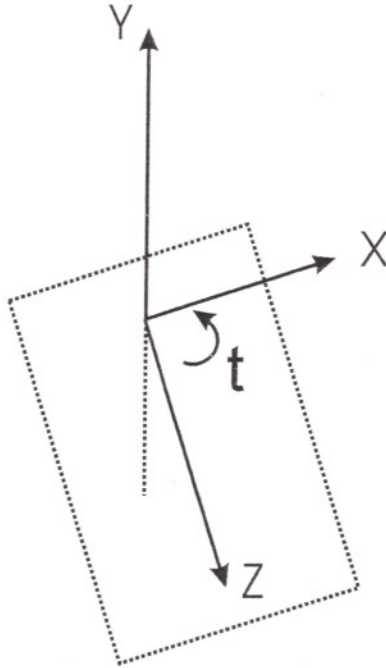


Figure 4.4: The couch coordinate space

4.4.5. PATIENT COORDINATE SYSTEM DEFINITIONS

The patient space is described in Section 2.1, and illustrated in figure 2. The axes of the patient space are parallel to those of the couch space. The linear displacements between the origin of the patient space and the treatment machine isocenter are used in subsequent coordinate system transformations. See figure 4.5.

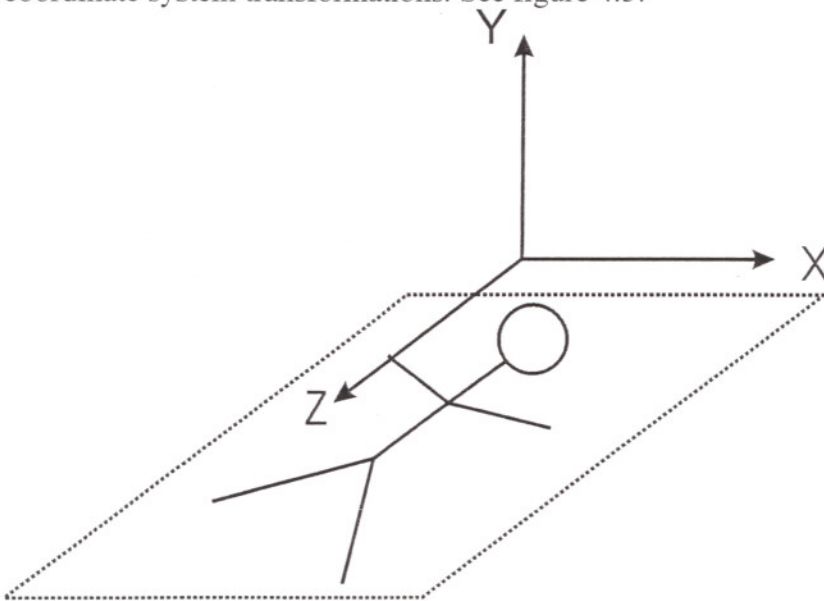


Figure 4.5: The Patient coordinate space

4.4.6. VIEWING COORDINATE SYSTEM DEFINITIONS

This space is a single planar crosssectional view of the patient. Three kinds of cross-sectional views are provided by the Curie Plan system: transverse, sagittal and coronal views. These are planes that are normal to the patient space z-axis, x-axis and y-axis, respectively. Associated with a view plane is a two dimensional coordinate system, and a scalar value determining which plane in patient space corresponds to the view plane. The origin in the view plane is the intersection with the plane of a line normal to the plane and through the patient origin. Section 2.18 describes these three view coordinate systems.

4.4.7. SCREEN COORDINATE SYSTEM DEFINITIONS

This space is a two-dimensional space, which represents the window on the display console. The origin of this space is in the upper left corner of the screen. The x-axis points to the right and the y-axis points down. Furthermore, the scale is in pixels, rather than centimeters. Screen space can be derived from view space by inverting the y-axis and rescaling (described below). See figure 4.6.

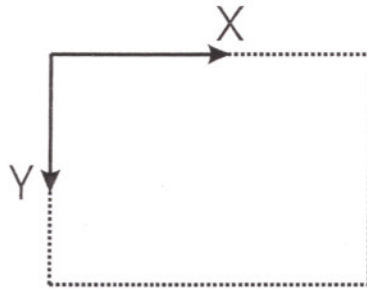


Figure 4.6: The screen coordinate space

4.5. USED GEOMETRIC TRANSFORMATIONS AND THEIR DERIVATIONS

The natural coordinate system for describing beams is collimator space. Most other graphical objects, like anatomy, tumors, and points (referred to below as contour or point based), are defined in patient space. The coordinates of these structures must be transformed to view space (and then to screen space) for the appropriate view being displayed. The drawing transformations can be divided into three categories: those for transverse views, those for sagittal and coronal views, and those for beam's eye views. In each category, different mechanisms are responsible for drawing the beams and the structures defined in patient space into the view. The x-origin and y-origin attributes of a view are set by the initialization code for each type of view, according to the value of the table position attribute of the plan containing the view. This default for cross-sectional views is that the table position point appears centered in the view. The origin is therefore computed by the following formulas, where, in each, x_o is the x-origin value, x_{pix} is half the view window width in pixels, x_{pat} is the x coordinate of the table position, and S is the scale factor in pixels per centimeter. Similar subscript conventions hold for the y and z coordinates [19].

For transverse views,

$$x_0 = x_{pix} - x_{pat} \cdot S \quad (4,6)$$

$$y_0 = y_{pix} - y_{pat} \cdot S \quad (4,7)$$

To draw a beam into a transverse view, one needs to transform the beam portal contour from collimator space to screen space. This involves cascading the following sequence of transformations:

Collimator \rightarrow gantry \rightarrow room \rightarrow couch \rightarrow patient \rightarrow view \rightarrow screen

These steps can be performed by the following detailed transformations:

1. From collimator to gantry, rotate about z by θ_c

$$x_{gantry} = x_{coll} \cdot \cos \theta_c - y_{coll} \cdot \sin \theta_c \quad (4,8)$$

$$y_{gantry} = x_{coll} \cdot \sin \theta_c + y_{coll} \cdot \cos \theta_c \quad (4,9)$$

$$z_{gantry} = z_{coll} \quad (4,10)$$

2. From gantry to room, first rotate about y by θ_g

$$x_{temp} = x_{gantry} \cdot \cos \theta_g - z_{gantry} \cdot \sin \theta_g \quad (4,11)$$

$$y_{temp} = y_{gantry} \quad (4,12)$$

$$z_{temp} = -x_{gantry} \cdot \sin \theta_g - z_{gantry} \cdot \cos \theta_g \quad (4,13)$$

Then rotate about x by 90° :

$$x_{room} = x_{temp} \quad (4,14)$$

$$y_{room} = z_{temp} \quad (4,15)$$

$$z_{room} = -y_{temp} \quad (4,16)$$

3. From room to couch, rotate about y by θ_t :

$$x_{couch} = x_{room} \cdot \cos \theta_t - z_{room} \cdot \sin \theta_t \quad (4,17)$$

$$y_{couch} = y_{room} \quad (4,18)$$

$$z_{couch} = x_{room} \cdot \sin \theta_t + z_{room} \cdot \cos \theta_t \quad (4,19)$$

4. From couch to patient, displace by the distance from the treatment machine isocenter to the origin of patient space:

$$x_{pat} = x_{couch} - lat \quad (4,20)$$

$$y_{pat} = y_{couch} - ht \quad (4,21)$$

$$z_{pat} = z_{couch} - long \quad (4,22)$$

where lat, ht, and long are the couch lateral, height, and longitudinal displacements respectively.

5. The transformations from patient to view space and view to screen space are discussed above. Note that in this case, the patient to view space transformation is not entirely trivial, since the displacement of the view along the z-axis has a bearing on which part of the beam portal intersects the view. Also note that between these two transformations, an intersection of the beam in view space with the view itself is performed. The beam portal, which is a three dimensional rectangular pyramid, is intersected with the plane of the view, and the line segments comprising this intersection are then transformed to screen space. Look ref [19] for details of the intersection operation.

If the view space coordinates of the isocenter and beam source is unequal, the central axis will cross the plane of the view somewhere. The x and y coordinates of the point of intersection can be computed via a similar triangles calculation involving the beam source and isocenter in view space:

$$\frac{x_{isec} - x_{src}}{x_{iso} - x_{src}} = \frac{z_{isec} - z_{src}}{z_{iso} - z_{src}} \quad (4,23)$$

where x_{isec} and z_{isec} are the x and z coordinates respectively of the intersection of the central axis with the view plane, x_{src} and z_{src} are the x and z coordinates of the beam source transformed into view space, and x_{iso} and z_{iso} are the coordinates of the isocenter transformed into view space. Since $z_{iso} = 0$, the equation can be solved for x_{isec} . The case for finding the y coordinate of the point of intersection is similar. This point of intersection is then transformed into screen space and displayed [19].

If neither of these cases applies, then the source and isocenter points must be parallel to and not coincident with the plane of the view, and will never intersect the plane, so nothing is drawn.



5. PROGRAMMING STRUCTURE AND CLASSES

5.1. DESIGNED CLASSES AND THEIR MEMBERS

Curie Plan has many classes to make its jobs. Additionally, some external classes are also used for making some complicated jobs. See figure 5.1 for complete list.

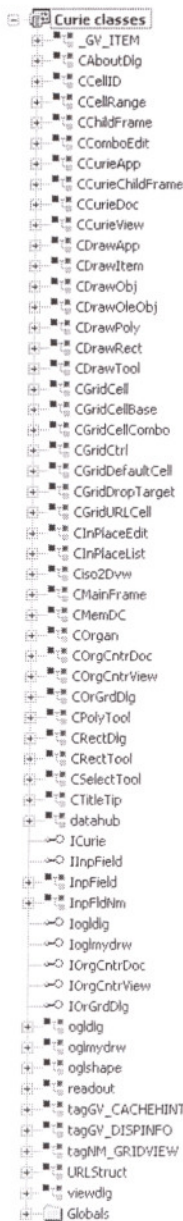


Figure 5.1: Class and Structure List

Struct GV_ITEM:

This structure is used for Get/SetItem calls. It is a sub data storage structure for CgridCtrl.

```
typedef struct _GV_ITEM {
    int      row,col;      // Row and Column of item
    UINT     mask;        // Mask for use in getting/setting cell
    UINT     state;       // cell state (focus/hilighted($) etc)
    UINT     nFormat;     // Format of cell. Default used.
                                // CDC::DrawText formats
    CString  szText;      // Text in cell
    int      iImage;      // index of the list view item's icon
    COLORREF crBkClr;     // Background colour (or CLR_DEFAULT)
    COLORREF crFgClr;     // Foreground colour (or CLR_DEFAULT)
    LPARAM   lParam;      // 32-bit value to associate with item
    LOGFONT  lfFont;      // cell font
} GV_ITEM;
```

Class CaboutDlg:

This class is designed for Main Application's About box control. It shows simple version information of the Curie Application, its icon, OK and Cancel Control Buttons.

Class CcellID:

This is a handy helper class used to reference individual cells. All members are public. It is a part of MFC Grid Control. This class is adapted from Joe Willcoxsons original implementation.

Class CcellRange:

This is a handy helper class used to reference cell ranges. It is a part of MFC Grid Control. This class is adapted from Joe Willcoxsons original implementation.

Class CchildFrame:

This class is designed for frame wrapper for Contour Editor.

Class CcomboCell:

This is an inplace active Combo Box Cell. It is a part of MFC Grid Control.

Class CcurieApp:

This is the main application entry point. Application Class is the first entry Frame call point of Foundation Class. Necessary initializations before any application window opening is done by this class. Document templates are created and this class does their memory allocations. Also basic file management events (FileOpen, FileSaveAs etc.) are handled and necessary variable initializing is carried out respectively.

Class CcurieChildFrame:

This class is designed for frame wrapper for Isodose 2D view and text log file view class.

Class CcuriDoc:

Application Patient data operations are handled by CcuriDoc Class. This class manages patient file storage work, ini file and log file. Also it does coordination of view class of 2D Isodose view and log view.

Class CcurieView:

This Class handles log view events coming from the operating system. It has a base class CeditView of Foundation Class. Scrolling, font management and other required jobs are done by the Foundation. User can not edit log text. Log text and its associated files are use not only for information, also used for security purposes.

Class CdrawItem:

Used for storing, deleting and manipulating of contour nodes. Nodes of Contours (or polylines) are stored in a pointer list. These List items are stored in to memory dynamically. Adding more than allocated point memory causes automatic increase of memory allocation.

Class CdrawObj:

Basic attributes of the contours (like its color, bounding box, filling type if exist etc.) are defined and manipulated here. It supports dynamic class generation.

Class CdrawOleObj:

Adds OLE event handling to CdrawObj class. In this project, this feature is not used. But external OLE objects can be taken into document in the feature. This Class can render OLE object both for screen and hardcopy devices such as plotters, printers and others. In place activation can also be easily activated in the project.

Class CdrawPoly:

Basic geometric calculations and data serialization is carried out by this Class. Intersection area between given rectangle and the active polyline region is determined by the intersection public member function of this class. Also a given point to a line segment that is a part of active contour or polyline, distance is calculated by CalcDistance public member function of this class.

Class CdrawTool:

This class handles selection, editing and creation of drawing contours works initially. This class redirects the necessary event messages to their correct handlers. Mainly

mouse movements, mouse clicks and last mouse positions are stored and redirected to CselectTool and CpolyTool Classes.

Class CgridCellBase:

This class is the base class for all grid cell classes, and holds the information for each cell. The class also defines a number of methods that are called by the grid itself, such as drawing and printing. Almost all methods and functions are virtual and this class is not designed to be used directly - rather it should be derived from. The default class CGridCell is derived from CgridCellBase and is used by the Grid control as the default cell class. It is a part of MFC Grid Control.

Class CGridCell:

This class is derived from CGridCellBase and provides a default implementation for use with CGridCtrl. It is a part of MFC Grid Control [20].

Class CgridCellCombo:

The grid cells can be of any type as long as the class is derived from CGridBaseCell. Included with the package is a CGridCell class that handles basic data storage and editing. Extensions such as the CGridCellCombo and CGridURLCell class demonstrate how to create your own cell classes.

Class CgridCtrl:

This class is Control Class of Grid Control. Necessary communications between application and the grid is carried out by this class. By Notify method of Event handling mechanism, backward messages can be send to application from grid content to owner. Keyboard and mouse inputs are filtered first by the grid itself.

Class CgridDefaultCell, CgridDropTarget, CgridUrlCell, CinPlaceEdit, CinPlaceList

Class Ciso2Dvw:

2Dimensional planer isodose curves are generated in this class. And curves are drawn to screen by line segments. In this class 5 zoom levels can be applied to both screen and printer output. In addition to these, also created contours and some basic necessary values are drawn. By mouse click, whole drawing area can be shifted up, down, left and right directions [19,20].

Class CmainFrame:

It creates main application window. It is derived from CMDIFrameFrameWnd. The CMDIFrameWnd class provides the functionality of a Windows multiple document interface (MDI) frame window, along with members for managing the window. Member variables are added to the derived class to store data specific to Curie application. Implement message-handler member functions and a message map in the derived class to specify what happens when messages are directed to the window.

Class CmemDC:

This class creates a virtual memory Device Context for screen output. But it can not be used for hardcopy devices such as printers, plotters etc. Dynamically compatible device context is created and freed on the fly.

Class Corgan:

Organizes the Organ and tumor contours and their attributes. Depth of cutting plane, present organs at that depth, their selections, creations are all done by this class. A list view shows available organs at that depth to user and redirects these data to contour editor for editing session.

Class CorgCntrDoc:

This class is derived from Cdocument base class. It handles Carchive pipes to serialize disk files for reading and writing. It can handle Clipboard functions as well. Cut, copy, paste, delete editing actions can be used by the user. And their keyboard accelerators are also supported. It will be discussed in detail in Chapter 9.

Class CorgCntrView:

Contour editor user interactions are handled by this class mainly. It handles mouse and keyboard information. It creates new contour polylines for different organ types, edits nodes, and adds new nodes. It will be discussed in detail in Chapter 9.

Class CorGrdDlg:

It shows numerical data of the contour positions. In the feature release, user can edit these values manually to obtain more precise positioning. Now it can be used only for verification purpose.

Class CpolyTool:

Its job is to show elastic rubber band to user. It connects two points. These two points generate a line segment of the contour after clicking the mouse. Mouse movements and mouse buttons are sent to this class from windows.

Class CrectTool:

Used for a rectangular selection. It selects groups of objects inside the selection rectangular.

Class datahub:

This class is used for multipurpose data storage. Patient, beam, contour, calculation cube, gantry position and couch position informations are stored into this class members. Treatment Machine specific informations are read from disk file.

Class InpField:

Handles beam field dialog events and its contents. It collects beam data from user. It handles required EditBox spaces.

Class InpFldNm:

This class is a Dialog box control class. Takes selected field information and sends this information to InpField class. It can handle up to 10 fields. Unavailable fields are grayed out. Only defined field options can be selected. From keyboard acceleration list, user can select a field by pressing its number such as 1,2...10 and press Enter key to select it and close this box.

Class Ogldlg:

This class is a OpenGL 3D view dialog control class. It handles OnTimer event to draw 3D scene to screen periodically. Takes drawing data from datahub class.

Class Oglmydrw:

Draws complicated parts of the treatment room parts. Most important parts are Walls of the room, machine base, machine arm, patient couch and x, y, z axis.

Class Oglshape:

This class is a part of class implementation of Silicon Graphics OpenGL primitive drawing shapes library. It draws solid box and 3d line segment.

Class Readout:

Reads, writes in and out files of the patient specific information. Class reads data from in and beamdata file to datahub. And it writes data from datahub class to disk files.

Class ViewDlg:

In the 3D OpenGL derived view, Object selection to view is made into this class. Reads radio button states from Dialog and sets appropriate members of data hub accordingly.

5.2. CLASS HIERARCHIES

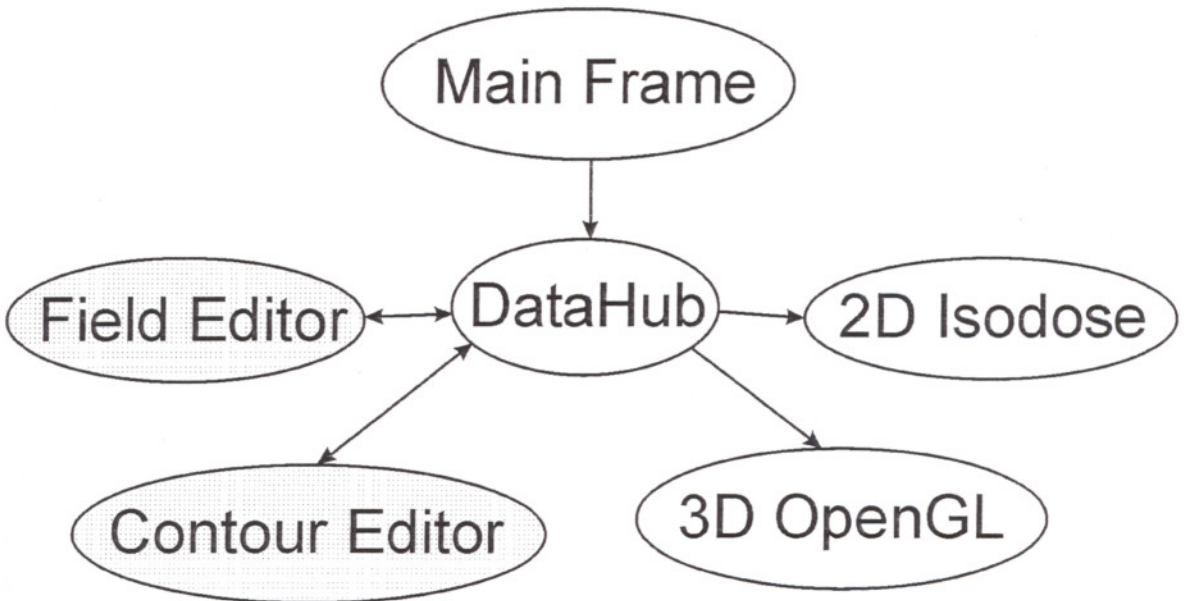


Figure 5.2: Class Hierarchies.

CmainFrame derived class is the entry point of this application. Datahub is connected with other view and edit classes. datahub class communicates with these classes by using direct pointer or Cdocument convention. Cdocument communication is very useful because it handles serializing the information.

Field Editor and Contour Editor Class communicate with DataHub in two ways. They can read and write data to datahub.

2D isodose and 3D OpenGL view classes can only read data from datahub [21].

5.3. APPLICATION MAIN MANAGEMENT CLASS

CmainFrame Class manages all classes. It allocates necessary memory spaces, creates objects and removes them from memory.

This MainFrame creates windows. Positions of the created windows can be calculated with the available space of the current mainframe and the size of the created window. These values can be found as follows:

```
Int x = GetSystemMetrics(SM_CXSCREEN); // Get Screen X Size in pixels
Int y = GetSystemMetrics(SM_CYSCREEN); // Get Screen Y Size in pixels

Crect rect;          // Get View Size and position info into rect
structure
GetWindowRect (rect);
```

So window can be placed optimally. In this project whole client area except toolbars, status line and right-placed Organ and Field Dialogs, are used for isodose view and Contour Editor view. If the screen coordinates are different. For example for SVGA 800x600 resolution or for XVGA 1024x768 pixels resolution can be used effectively.

First, Datahub class is created. Because Datahub is used by all classes to communicate between them.

5.4. INTERCOMMUNICATIONS BETWEEN CLASSES

First, Datahub class is created. Datahub is used by all classes to communicate. Also Global variables and MainFrame member variables can be accessed any where of the application.

In the opening, application reads its state variables from curie.ini file. And stores last state to this file at the closing of the application.

Any data change in the current planning parameters causes a message sending to all other. So other informed views are updates their client areas.

5.5. JOBS OF THE CLASSES

Most important classes generated in this project are:

- Datahub
- CcurieApp
- CmainForm
- CcurieDoc
- CcurieView
- CgridCtrl
- Ciso2dvw
- CorgCntrView
- Corgan
- InpField

DataHub

This class stores patient, beam, geometry, and state information. It handles all important data about planning patient. It's content will be discussed in detail at the next section.

CcurieApp

It is the first entry point of the application. Operating System Loads Application executable into memory and gives control to application entry point of this class. Windows NT is a multitasking Operating System. And this application does not check its other instances in the memory. So more than one of these applications can be executed at the same time. But user must be careful to use different patient files. Program does not check or lock any data file while working. If different instance of application uses same data file, many unwanted side effects can occur. In this class internal Operating System DoPromptFileName function is overridden. So application opens directly last working directories to load patient files.

CmainForm

This Class creates main window of the application. Creates menu, tool bar, and status bar. Also defines document-frame-view structures for 2D isodose, 3D OpenGL View, Organ Contour Editor CorgCntrView and InpField Dialog. Sets global variables to their initial values. Initial Window positions are calculated and performed by this Class. At the termination of the application all created classes and this Class deletes their contents. Status line updates are done by this class.

CcurieDoc

Serialization of patient data and curie.ini file handling is done by this class. The CCurieDoc class provides the basic functionality for user-defined document classes. A document represents the unit of data that the user typically opens with the File Open command and saves with the File Save command. CCurieDoc supports standard operations such as creating a document, loading it, and saving it. The framework manipulates documents using the interface defined by this class. The framework also prompts the user to save a modified file before closing it. Serialization is done by using CArchive class.

The CArchive class allows you to save a complex network of objects in a permanent binary form (usually disk storage) that persists after those objects are deleted. Later you can load the objects from persistent storage, reconstituting them in memory. This process of making data persistent is called "serialization."

You can think of an archive object as a kind of binary stream. Like an input/output stream, an archive is associated with a file and permits the buffered writing and reading of data to and from storage. An input/output stream processes sequences of ASCII characters, but an archive processes binary object data in an efficient, nonredundant format.

CcurieView

This class is used for Logging of the planning session. It is used for security. Any usage of this application must be under control of the user clinic. Log file tracks any modification made to plan. This class is derived from CeditView Class of MFC foundation. A CEditView object is a view that, like the CEdit class, provides the functionality of a Windows edit control and can be used to implement simple text-editor

functionality. The CEditView class provides the Printing function. In this application, CcurieView is kept read only. Users can not edit or delete or add any line of text.

CgridCtrl

It is very complicated class. It is used for spreadsheet like functionality. User can see and edit numerical data in the tabular form. Any number of row or column data can be used. Data can be changed by using mouse or keyboard. Sorting, adding, deleting and changing can be easily done.

Ciso2dvw

It is derived from CscrollView. It manages window and viewport sizes and mapping modes. It scrolls automatically in response to scroll-bar messages. It scrolls automatically in response to messages from the keyboard, a non-scrolling mouse, or the IntelliMouse wheel.

This class shows Organ Contours and defined isodose curves. It does its job using finite pre-calculated matrix.

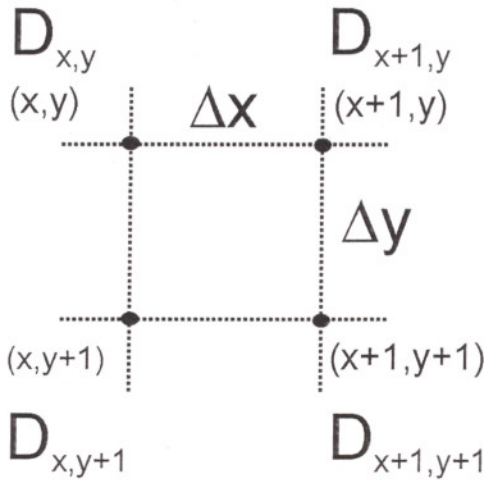


Figure 5.3: Dose Square

By using similar triangle and linear interpolation, any required dose at the given point can be calculated with a small rounding error. Connecting these equal dose points with small line segments, isodose curves are generated (see figure 5.3 and 5.4).

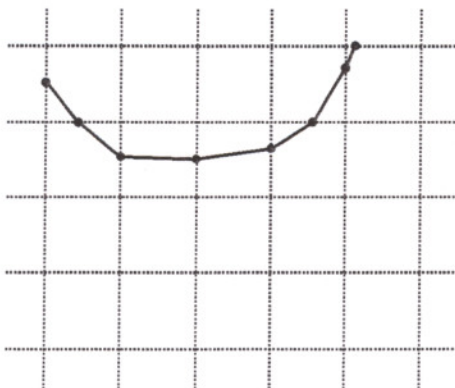


Figure 5.4: Generated Isodose Curve Sample.

CorgCntrView

This class is used for drawing and editing of the organ contours. Detailed explanations will be discussed in Chapter 9.

Corgan

This class is used for managing of different contour depth slices. Each slice can have more than one contour. It has a CDialog class derived Dialog Box. It has a list view. This list view shows available depths. And displays created organs in this list by putting X sign. So user can easily see which organs are defined at which depths or not. Any slice can be deleted or a new slice can be added to database in the datahub. By calling Contour Editor, current editing depth is set and new Contour editor classes are created and started.

InpField

Collects and shows beam-field information in the associated field Dialog. Field name, field type, collimator size, field id number, field attenuation factor and its modifiers are managed in this class. New field generation, field editing and field erasing is done by this class also. It uses the field selection dialog box to determine user field id selection.

5.5.1. DATA HUB CLASS

Datahub Class stores following data records:

- Beam Data Record has mainly these parameters
- Contour Data Record
- CubeSpec Data Record
- Field Data Record
- Couch Positioning
- Organ Contour Data Record

Detailed contents of the records:

- Beam Data Record has mainly these parameters:

- Beam Name (Null terminated character string)
- CalcDistance (floating point number)
- Type of Beam (Photon, Neutron or Electron)
- SSD (Skin to Source Distance)
- OCR Tables (floating point number)
- Output Factors (floating point number)
- Collimator_ID (integer value)
- SPR Tables (Source Phantom Ratio) (floating point number)
- TPR Tables (Tissue Phantom Ratio) (floating point number)
- Wedge Count (integer)
- Wedge Profiles (floating point number)

- Contour Data Record:

- Next Contour pointer
- Points (int x and int y)
- Z value (floating point number)

- CubeSpec Data Record:

- Dimensions of x, y and z (floating point number)
- Origin of x, y and z (floating point number)
- Size of x, y and z (integer number)

- Field Data Record:

- Collimator x-left, x-right of lower and higher jaws positions (floating point number)
- Beam Name (Null terminated character string)
- Beam Type (integer)
- Attenuation Factor (floating point number)
- Gantry Angle (floating point number)

- Couch Positioning:

- Lateral, longitudinal, vertical positions (floating point number)
- Couch Angle (floating point number)

- Organ Contour Data Record:

- Number of Organs
- Density of the organ (floating point number)
- Number of Contours (integer)
- Contour points (x and y pair of floating number)
- Contour Type (integer)

5.5.2. CDOCUMENT, CVIEW, CFRAME AND OTHER MFC DERIVED CLASSES

The following figures 5.6 and 5.7 give an overview of the creation process for documents, views, and frame windows.

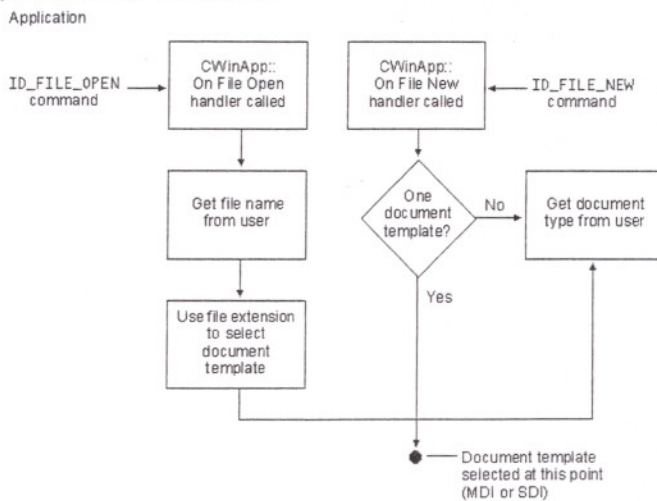


Figure 5.5: Creating a document

After File open or File New command, Frame and View creation is started. In the Figure 5.6, Frame and View creation steps are described in the form of a flow chart.

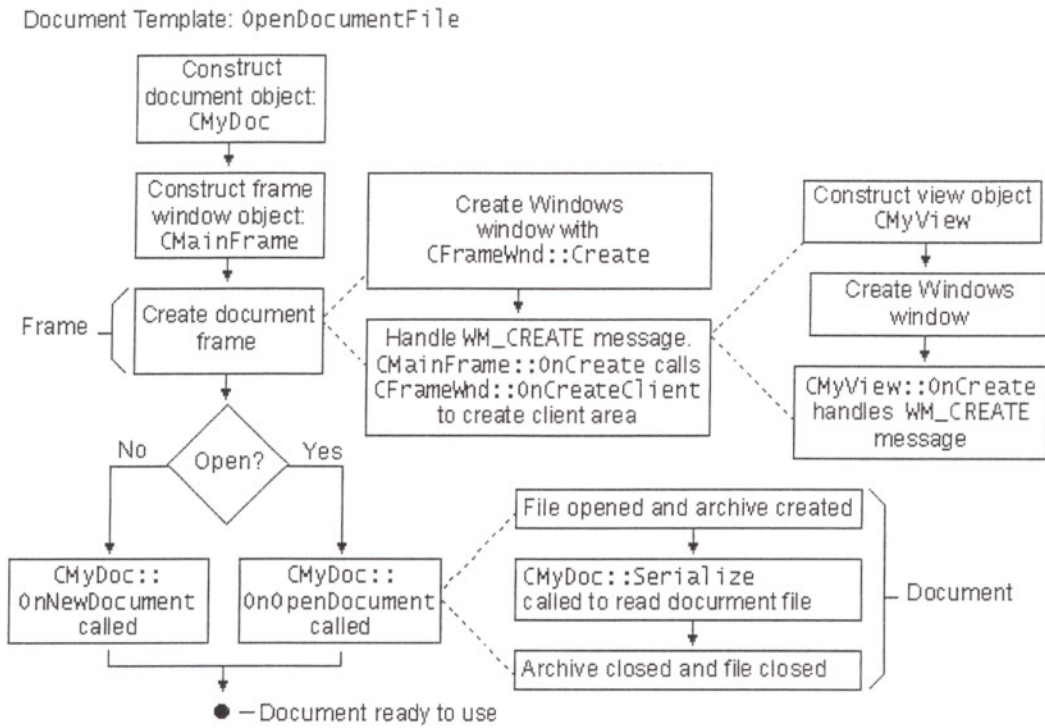


Figure 5.6: Sequence in Creating a Frame Window

Upon completion of this process, the cooperating objects exist and store pointers to each other. The following figures show the sequence in which objects are created.

The CView class provides the basic functionality for user-defined view classes. A view is attached to a document and acts as an intermediary between the document and the user: the view renders an image of the document on the screen or printer and interprets user input as operations upon the document. In this project, CScrollView, which is derived from Cview class, is used to visualize data. A view can be attached to only one document, but a document can have multiple views attached to it at once. For example, Log view, OpenGL view, isodose view and Contour Edit view all are connected to main document file. A view is a child of a frame window. More than one view can share a frame window. A view may be responsible for handling several different types of input, such as keyboard input, mouse input or input via drag-and-drop, as well as commands from menus, toolbars, or scroll bars. A view receives commands forwarded by its frame window. If the view does not handle a given command, it forwards the command to its associated document. Like all command targets, a view handles messages via a message map [20,22,23,24].

The view is responsible for displaying and modifying the document's data but not for storing it. The document provides the view with the necessary details about its data. Programmer can let the view access the document's data members directly, or he/she can provide member functions in the document class for the view class to call.

5.5.3. CDRAWCLI CONTOUR EDITOR AND ITS SUBCLASSES

Contour Editor is mainly based on the `CDrawCli` class. All drawing shapes are different objects. `DRAWCLI` is an object-oriented drawing application with Visual Editing container support. This subclass provides the best illustration of integrating Active container support with application-specific features (in this case, drawing features). In addition, `DRAWCLI` demonstrates effective use of C++ polymorphism in the design of its "shape" and "drawing tool" classes (`CDrawObj` and `CDrawTool`) [20].

Class `CDrawObj`, implemented in `Drawobj.cpp`, is a base class for derived "shape" classes. This base class handles hit testing of shapes, moving of shapes, and resizing of shapes. Through the use of polymorphism, `DRAWCLI` can interact with objects of different classes through `CDrawObj` interface.

Classes `CDrawRect` and `CDrawPoly` are derived from `CDrawObj`. `CDrawRect` is used to draw rectangles, rounded rectangles, ellipses, and lines. `CDrawPoly` is used to draw polygons. These two classes are independent of `DRAWCLI` container functionality [20].

Class `CDrawOleObj` is also derived from `CDrawObj`, and is used to represent embedded objects. `CDrawOleObj` delegates any Operating System specific operation to a contained `CDrawItem` object (described below). For generic shape operations, embedded objects are treated like other shape objects in `DRAWCLI` because `CDrawOleObj` is derived from `CDrawObj` [20].

Class `CDrawItem`, derived from `COleClientItem`, handles all the ActiveX-specific behavior for the embedded object. The implementation of `CDrawItem` is similar to the implementation of the `COleClientItem`-derived classes.

Class `CDrawDoc` is derived from `COleDocument`. The `COleDocument` object maintains a `CObjList` of `CDrawObj` objects. `CDrawDoc` delegates several container-specific menu commands, such as Edit Paste, Paste Link, and Links, to the base class `COleDocument`.

Class `CDrawView` is derived from `CScrollView`. The ActiveX-specific implementation of `CDrawView` is similar to the implementation of the view classes in the `CONTAIN` and `OCLIENT` samples. The bulk of `DRAWCLI` drawing-specific user interface is also implemented in `CDrawView`.

5.5.4. FORM AND OPENGL VIEW CLASSES

OpenGL is an industry-standard three-dimensional software interface. As a hardware-independent interface, the operating system needs to provide pixel format and rendering context management functions. Windows NT provides a generic graphics device interface (GDI) implementation for this as well as a device implementation. This article details these implementations, OpenGL/NT functions, and tasks that applications need to accomplish before OpenGL commands can be used to render images on the device surface. OpenGL is pretty much the industry standard for high-quality 3D graphics applications. If you admired the dinosaurs in Jurassic Park, then you were looking at an

OpenGL application. A big advantage of OpenGL is that it's platform-independent; it's available on a variety of hardware platforms and operating systems, including Windows 95, Windows NT, OS/2, DEC's AXP and Open VMS, and X Windows [21].

It is an industry-standard procedural software interface for producing 3-D graphics. It does so by providing roughly 120 commands to draw various primitives including points, lines, and polygons in various modes. With OpenGL, you can create high-quality still and animated 3-D color images.

More seriously, OpenGL/NT calls are intercepted by the installable client driver [20]. The client driver packages these OpenGL and WGL commands and sends them to the video display driver. The video display driver is linked with libraries that contain dispatch functions, OpenGL code, and some portable low-level drawing support functions. The big win with OpenGL support in the video driver and appropriate hardware is speed. Rendering can be accelerated tremendously. See figure 5.7.

The CFormView class is the base class used for form views. A form view is essentially a view that contains controls. These controls are laid out based on a dialog-template resource. Use CFormView if you want forms in your application. These views support scrolling, as needed, using the CScrollView functionality.

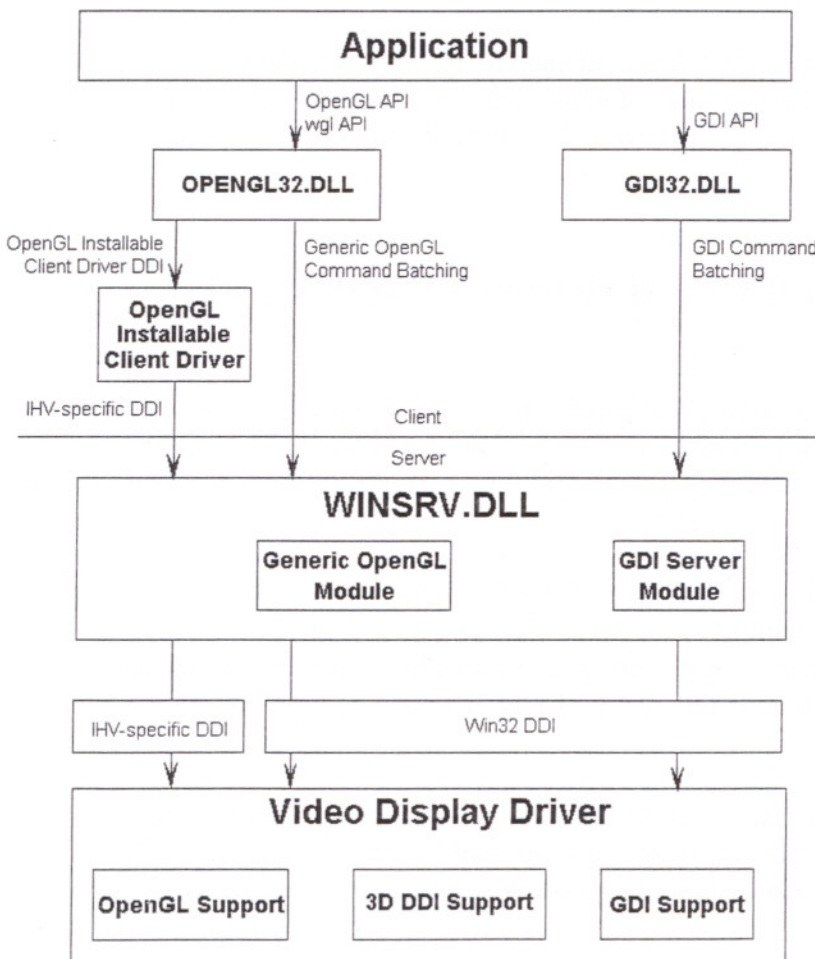


Figure 5.7: OpenGL Architecture

6. FILE MANAGEMENT

6.1. MFC FILE MANAGEMENT PRINCIPLES AND USAGE IN THIS PROJECT

In MFC, file open, save and new is supported in a very easy way. But programmer should write his/her code to satisfy MFC requirements. In the following topics these restrictions will be discussed in detail. CArchive class object sends a pointer to CDocument member functions. So, only piping routines are enough for streaming the data. Some state variables are used to determine if there is a change in the document. If there is any change, save request is generated from Framework. Programmer can check this status by controlling the ModifiedFlag status. Or user can overwrite the ModifiedFlag [20].

When user closes the application, Framework checks ModifiedFlag status. If ModifiedFlag is TRUE it calls OnFileSave member function. If there is no assigned work file name, a filename dialog box appears on the screen.

In this project, there is more than one type of document. Especially, some files are prepared outside the application. So these files, for example scanned image files are read or write manually by the application itself not from Framework.

6.2. CARCHIVE AND CDOCUMENT CLASS AND DATA STREAMING TO DISK

A CArchive object provides a type-safe buffering mechanism for writing or reading serializable objects to or from a CFile object. Usually the CFile object represents a disk file; however, it can also be a memory file (CSharedFile object), perhaps representing the Clipboard.

A given CArchive object either stores (writes, serializes) data or loads (reads, deserializes) data, but never both. The life of a CArchive object is limited to one pass through writing objects to a file or reading objects from a file. Thus, two successively created CArchive objects are required to serialize data to a file and then deserialize it back from the file [20].

The parts of the MFC framework most visible both to the user and to you, the programmer, are the document and view. Most of your work in developing an application with the framework goes into writing your document and view classes. This article family describes:

The purposes of documents and views method organizes how they interact in the framework.

The `CDocument` class provides the basic functionality for programmer-defined document classes. A document represents the unit of data that the user typically opens with the Open command on the File menu and saves with the Save command on the File menu.

The `CView` class provides the basic functionality for programmer-defined view classes. A view is attached to a document and acts as an intermediary between the document and the user: the view renders an image of the document on the screen and interprets user input as operations upon the document. The view also renders the image for both printing and print preview.

Figure 6.1. Shows the relationship between a document and its view.

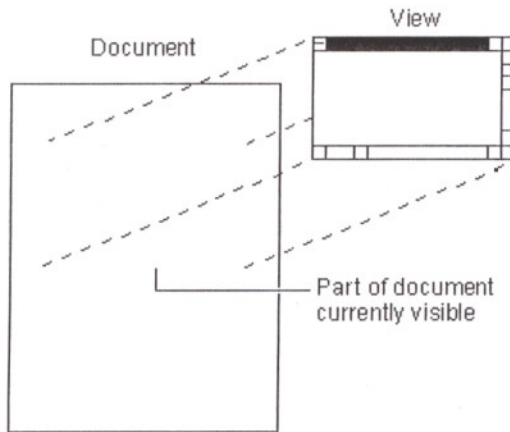


Figure 6.1: Document and View

The document/view implementation in the class library separates the data itself from its display and from user operations on the data. All changes to the data are managed through the document class. The view calls this interface to access and update the data.

Documents, their associated views, and the frame windows that frame the views are created by a document template. The document template is responsible for creating and managing all documents of one document type.

6.3. DATA STRUCTURES OF DISK FILES

The main idea is storing data to a `Carchive` object by piping method, [22].

```
void CCurieDoc::Serialize(CArchive& ar)
{
    if (ar.IsStoring()) { // Storing Procedure.

        Destination = GetDataHub()->GetCurrentPatientDataFilePaths();
        ar << Destination;
        PatientID = GetDataHub()->GetCurrentPatientDataFileName();
        ar << PatientID;
        ((CMainFrame*)AfxGetApp()->m_pMainWnd)->readoutDlg->write_in_file(0);
        //0:means for Store 1: for Calc.

        CEditing.SetReadOnly(TRUE);
        CEditing.SetSel(0,0,FALSE);
        CEditing.SetSel(0,-1,FALSE); CEditing.SetSel(-1,0,FALSE);
        CEditing.ReplaceSel("Working file have been stored to disk on " +
            GetTimeString() + "\r\n",TRUE);
    }
}
```

```

        SetModifiedFlag (FALSE) ;
        EditingCEditView->Serialize (ar) ;
    }
    else{
        // Loading Procedure.
        ar>>Destination;
        GetDataHub ()->SetCurrentPatientDataFilePaths (Destination) ;
        ar>>PatientID;
        GetDataHub ()->SetCurrentPatientDataFileName (PatientID) ;
        EditingCEditView->Serialize (ar) ;
        CEditing.SetSel (0,0,FALSE) ;    CEditing.SetSel (0,-1,FALSE) ;
        CEditing.SetSel (-1,0,FALSE) ;
        CEditing.ReplaceSel ("Working file have been restored from disk on " +
            GetTimeString () + "\r\n",TRUE) ;
        CEditing.SetReadOnly (TRUE) ;
        SetModifiedFlag (FALSE) ;
    }
}

```

6.4. TEMPORARY FOLDERS AND FILES

There is a temporary file directorie in the patient data directory. When user opens a working data file, a copy of this work and other related files are copied to this temporary directory. And real reading and writing operations are done with these files. These files can be patient identification file, log file or image files (cross sectional CT, MR film slices).

When application is closed or saved, application copies these working files from this temporary directory to real patient directory [25].

6.5. LOG FILE AND ITS CONTENTS

When a new planning session is started, a log file is generated. This is a text context file. User can not edit this text. Its attributes are set read-only. System reads log file content into memory when a patient file is opened.

Application initially puts some information about version and creation date at the beginning of the text. Log file is kept in memory in the form of CEdit class. For example programmers can add new lines to log content as follows:

```

// CEditing is predefined as Cedit Class

CEditing.ReplaceSel ("(c)Curie V1.0 Planning System 2001.\r\n",TRUE);
CEditing.ReplaceSel ("Planning Session Started on " + GetTimeString () +
"\r\n", TRUE);
CEditing.ReplaceSel (" - - - - - \r\n",
TRUE);

```

6.6. CT, MR, ROENTGEN IMAGE FILES AND THEIR PLACEMENTS

Negative printed medical films must be scanned into a bitmap file at the specified parameters. Resolution and size must be adjusted to meet requirements.

Scanning resolution must be 75, 150 or 300 dpi. And must be specified in the .bmp file structure correctly. Curie looks these informations (x and y component of the resolution) to calculate scaling factor. Any other resolution can cause wrong calculations. Or required modifications must be applied to source of the application by

the programmers. But higher resolution is not necessary. Because, 0,0847 mm precision is obtained from 300dpi resolution. Also, higher resolutions require huge amount of memory to handle these files. Therefore, higher resolution causes dramatical decrease in performance.

Each scanned file must be labeled as:

- Slice-10.bmp
- Slice10.bmp
- Slice20.bmp

“Slice” word should be place in the beginning of the filename. Following sign and number pair shows the depth of the slice in millimeters.

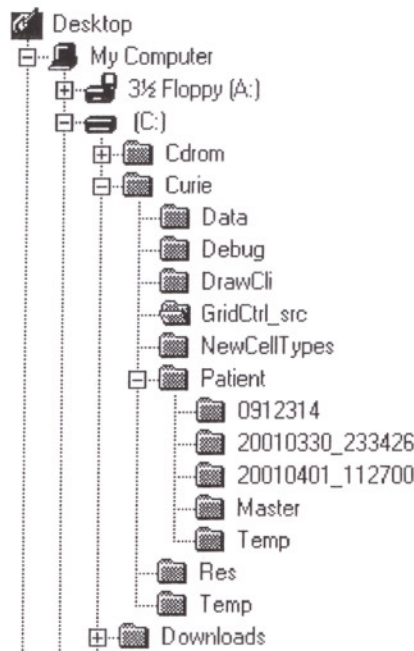


Figure 6.2: Sample Directory Structure

These scanned files should be stored into the patient specific directory. This directory is created when the patient file saved. So user must be create and save an empty patient file before placement of these image files. Format of the directory name is:

Year + month + day + ”_” + hour + minute + second

Year: 4-digit integer number.

Month, day, hour, minute, second: 2-digit integer number.

This time shows the creation time of the patient data file. So, system date and time must be correct. Also this method avoids any repetition in the directory and patient filename. So each directory can be unique [22, 25].

6.7. DATA EXCHANGE BETWEEN THE PROJECT AND THE OTHER POPULAR APPLICATIONS

Curie has a standard data structures both internal and external. Stores plan parameters in a systematic data files. This application may be run in a network environment either locally or on a remote host. Other external calculation servers take output from Curie, makes calculations and sends back. Or, more than one calculation server can be used to compare results and obtain more accurate results [24].

Each time a radiation source description is read, a dose computation program compliant with the protocol computes the dose distribution for that source. The protocol supports two styles of interaction with a program - a mode where results are written back after each radiation source is supplied, and a mode where results are accumulated and then returned after a number of sources have been read.

7. SOURCE CODE & RESOURCE ORGANIZATIONS

7.1. C++ SOURCE CODES AND THEIR JOBS

In this project, C++ programming language is used. Source codes are mainly placed in *.CPP files. Function prototypes, class definitions, variable and structures are placed in the *.H files. In some special cases, some member function bodies are included into header files directly [26].

Source filename	Class Content	Basic Job
ChildFrm.CPP	CChildFrame	Item management.
Curie.CPP	CCurieApp	Application Start + Init + End.
CurieDoc.CPP	CCurieDoc (Cdocument)	Cdocument handling + Read, Write and Store.
CurieView.CPP	CCurieView (CEdit)	Text View. Log file content.
DataHub.CPP	DataHub (CDialog)	Patient plan data (Beam + Contour + Isodose)
InpField.CPP	InpField (CDialog)	Beam information editor.
Iso2Dvw.CPP	Ciso2Dvw (CScrollView)	Visualization of 2D isodose and Contour curves
MainFrm.CPP	CMainFrame	Main Window Form Creation + init.
OglDlg.CPP	OglDlg (CDialog)	OpenGL 3D Room View.
OglMydrw.CPP	OglMydrw (user def.)	OpenGL primitives of Room parts.
OglShape.CPP	OglShape (user def.)	Silicon Graphics 3D object primitives.
Organ.CPP	Corgan (CDialog)	Contour Slice Selection and Management.
OrgCntrView.CPP	CorgCntrDoc + CorgCntrView	Contour Editor And Objects.
OrGrdDlg.CPP	COrGrdDlg	Spread sheet like data list.
Readout.CPP	Readout (CDialog)	Reads and writes patient import/export data.

Table 7.1: C++ Source Code List. In the paranthesis, base classes are shown.

In this project, two external Classes are used. Their source codes are included with other sources. First class is CDrawCli. But its original implementation is not enough. For examples, there is no support for addition of new nodes to prepared contours, see Table 7.2. Such new functions are added to this class. Second class is GridCtrl source. It is nearly in original form. It is very useful and functional, see Table 7.3.

Source filename	Class Content	Basic Job
Cntritem.CPP	CdrawItem	OLE + Bounding Box Calc.
Drawobj.CPP	CdrawObj + CdrawOleObj	Drawing Object Primitives
Drawtool.CPP	CdrawTool + CselectTool + CPolyTool	Selection and Editing Tools

Table 7.2: DrawCLI C++ Source Code List.

Source filename	Class Content	Basic Job
GridCellBase.CPP	CgridCellBase	Base Cell Structure
GridCell.CPP	CgridCell	Grid Cell Content
GridCtrl.CPP	CgridCtrl	Base Control Library
GridDropTarget.CPP	CGridDropTarget	Drag and Drop Support
InPlaceEdit.CPP	CinPlaceEdit	OLE Support
TitleTip.CPP	CtitleTip	TitleTip Support

Table 7.3: GridCtrl C++ Source Code List.

7.2. RESOURCES (MENU, ACCELERATOR, DIALOGS, CURSOR, TOOLS, ETC.)

Due to the preceding advantage list, companies which design PCs as controllers began to. Curie uses many types of windows resource. Used resources are Accelerators, Cursors, Dialogs, Menu items, Strings, Toolbar and version information.

Accelerators:

In the beginning of the Project, Application Creation Wizard Of The Visual C++ Studio created basic accelerators. Some useful accelerators were added later times, see Table 7.4. Usage of accelerator keys is not possible at the all places. For example, at the iso2dview clipboard functions (cut, copy, paste, etc.) do not work.

Key Combination	Job
Ctrl + C	Edit Copy to Clipboard
Ctrl + N	New Patient File
Ctrl + O	Open Patient File
Ctrl + P	Print
Ctrl + S	Save Patient File
Ctrl + V	Edit Paste from Clipboard
Delete	Edit Clear
Shift + Delete	Edit Cut
F6	Next Pane
Shift + F6	Previous Pane

Table 7.4: Accelerators List

Cursors:

Different types of cursors are mainly used in contour editor program. Contour editor's base class is CdrawCli. But CdrawCli class does not support node addition and context menu. To make this project user-friendlier, Different cursor shapes are added to project. Their jobs are listed in the Table 7.5.

Cursor ID	Jobs
IDC_STDADDNODE	Node Add is available
IDC_STDCUR	Standard Windows Arrow Cursor
IDC_STDEDITPREC	Hatch with plus sign, Editing + Node Add available.
IDC_STDPLS	Standard Windows Arrow with plus sign.

Table 7.5: Cursors ID versus their Jobs.

Dialog Boxes:

Many numerical and string inputs are shown and collected by Dialog Boxes. A List of Dialog Boxes in this project is listed in the Table 7.6.

Dialog Box	Jobs
IDD_ABOUTBOX	Short Version Explanation Dialog
IDD_DLG_ORGAN	Depth Selection, Contour Editing.
IDD_INPUT_FIELD	Beam parameter Editor Dialog
IDD_INPUT_FIELD_NUMBER	Selecting active beam form defined beams
IDD_OGL_VIEW_DLG	3D OpenGL View Object activation
IDD_OGLDLG	3D OpenGL View Area
IDD_ORGAN_CONTOUR_DATA_GRID	Tabulated Data View
IDD_ORGAN_CONTOUR_DRAW	Contour Editor View
IDD_READOUT	Import/Export View (Debugging purpose)

Table 7.6: Dialog Box and their jobs.

Menu Items:

There are 4 main menu items on the main application window. Help menu has only about item. Other 3 items are shown in Figure 7.1.

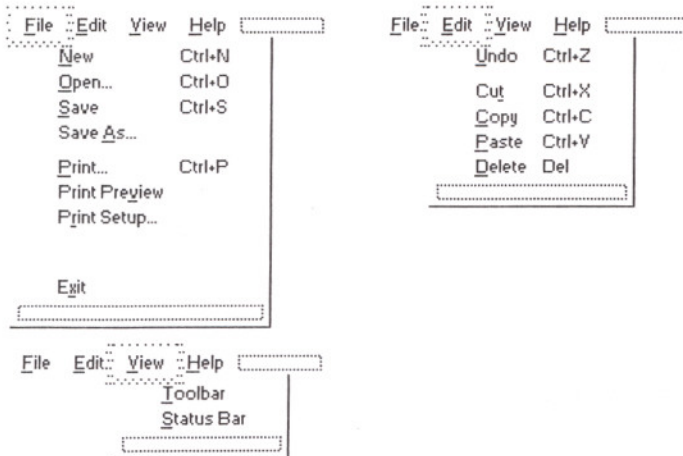


Figure 7.1: Menu Items.

String Table:

Resource ID	String Value
ID_FILE_NEW	"Create a new document\nNew"
ID_FILE_OPEN	"Open an existing document\nOpen"
ID_FILE_CLOSE	"Close the active document\nClose"
ID_FILE_SAVE	"Save the active document\nSave"
ID_FILE_SAVE_AS	"Save the active document with a new name\nSave As"
ID_FILE_PAGE_SETUP	"Change the printing options\nPage Setup"
ID_FILE_PRINT_SETUP	"Change the printer and printing options\nPrint Setup"
ID_FILE_PRINT	"Print the active document\nPrint"
ID_FILE_PRINT_PREVIEW	"Display full pages\nPrint Preview"
ID_APP_ABOUT	"Display program information, version number and copyright\nAbout"
ID_APP_EXIT	"Quit the application; prompts to save documents\nExit"
ID_NEXT_PANE	"Switch to the next window pane\nNext Pane"
ID_PREV_PANE	"Switch back to the previous window pane\nPrevious Pane"
ID_EDIT_CLEAR	"Erase the selection\nErase"
ID_EDIT_COPY	"Copy the selection and put it on the Clipboard\nCopy"
ID_EDIT_CUT	"Cut the selection and put it on the Clipboard\nCut"
ID_EDIT_PASTE	"Insert Clipboard contents\nPaste"
ID_VIEW_TOOLBAR	"Show or hide the toolbar\nToggle ToolBar"
ID_VIEW_STATUS_BAR	"Show or hide the status bar\nToggle StatusBar"
AFX_IDS_SCSIZE	"Change the window size"
AFX_IDS_SCMOVE	"Change the window position"
AFX_IDS_SCMINIMIZE	"Reduce the window to an icon"
AFX_IDS_SCMAXIMIZE	"Enlarge the window to full size"
AFX_IDS_SCRESTORE	"Restore the window to normal size"
AFX_IDS_SCTASKLIST	"Activate Task List"
AFX_IDS_PREVIEW_CLOSE	"Close print preview mode\nCancel Preview"
IDR_MAINFRAME	"The Curie Application"
IDR_CURIETYPE	"\nUntitled\nTEXT Document\nText Files (*.cri)\n.cri\nTextFileType\nTEXT File Type\nTEXT\nText Files\n"
IDR_CURIEISODOSE	"Isodose\ndosess\n\n\n\nTextFileType\nText File Type"

Table 7.7: String Value List.

Toolbar:

Most frequently used items have toolbar buttons. These items are:

File New, File Open, File Save, Cut, Copy, Paste, Print, and Help has a button on the toolbar.

Version:

File Version: 1,0,0,1
Product Version: 1,0,0,1
Product Name: Curie Application
Legal Copyright: Copyright (C) 2001
Original Filename: Curie.EXE

7.3. COMPILER PARAMETERS, REQUIRED LIBRARIES AND COMPILING

This project is written in C++ Language. Licensed Microsoft Visual Studio C++ 6.0 Academic Edition Compiler has been used. This package includes many visual and basic components. Compiler has many options to optimization and capabilities. To compile this project following parameters must be set:

```
Preprocessor def: WIN32, _DEBUG, _WONDDWS, _MBCS  
Project Options : /nologo /MTd /W3 /Gm /GX /ZI /Od /D "WIN32" /D  
                  "_DEBUG" /D "_WINDOWS" /D "_MBCS" /FR"Debug/"  
                  /Fp"Debug/Curie.pch" /Yu"stdafx.h" /Fo"Debug/"  
                  /Fd"Debug/" /FD /GZ /c
```

To open curie project, curie.dsw file must be opened from Open Workspace Menu item. Linker options must be specified as follows:

8. USER INTERFACE DESIGN AND THEIR USAGE

This chapter describes the usage of the Curie Plan V1.0 from the user's point of view. User interface capabilities and its functions are included in this chapter. The hardware and operating system requirements as well as installing and running of the Curie software are described.

8.1. BASIC PARTS AND THEIR FUNCTIONS

Shortly capabilities of the Curie planning V1.0 system are:

- Enter, edit, display and store demographics, clinical findings and other information about patients,
- Acquired and stored image studies from CT and MRI scanners (from disk files copied from the scanner computer by some network access method),
- Display and process stored images, including reconstructed contours.
- Enter, edit, display and store 3-D patient geometry including internal structures and locations of points of interest, based on anatomic data represented in stored image studies, or in films and tracings on paper,
- Enter, edit, display and store 3-D treatment plans consisting of collections of radiation sources including external radiation,
- Prescribe treatments by several different methods, including specifying doses to be delivered by particular radiation sources to specific anatomic points, and specifying the dose to be (nearly) achieved throughout extended volumes,
- Calculate doses at points and/or in 2-D planes, display doses as isodose contours superimposed on anatomy and markers, and store computed dose distributions for subsequent display,
- Produce hardcopy output presenting the graphical results of all the planning operations,
- Utilize all the products of the Radiotherapy Treatment Planning Tools project.
- Load and Save treatment setup data for subsequent download

System has standard windows user-interface tools. Because of some requirements, special add-ons have been included.

A view occupies a single window on the display, so it may be moved, "popped to the top" or manipulated by any of the standard operations provided by the window manager. Several views (in the corresponding windows) may be visible at the same time. All views are "active" views except 2D and 3D views, that is, if an object in the plan is updated, all views showing that object are updated to reflect the change. 2D and 3D views are used to visualize calculated data. Therefore, these views are updated, when new results are ready. Further, views provide some interactive input, e.g., the locator bars that control the view positions for other views, and the dose calculation grid, whose

corners may be "dragged" with the mouse and on-screen pointer. User can easily change window positions and sizes.

Main parts of the planning tools are:

- **Organ Contour Editor,**
- **Z-Depth Management,**
- **Treatment Beam Definition Dialog Box and Dose Grid Parameters,**
- **2D planer Isodose Curve Visualizer,**
- **3D Treatment Room Simulation View.**

8.2. ORGAN CONTOUR EDITOR

The Organ Contour Editor (also called the "polyline editor") is a composite CScrollView derived view that supports the creation and editing of organs, tumors, and targets. With this tool, user can select an organ to edit its node points. Or user can select one (or more by using rectangular selection) contour to move its place and group-erase.

Contour Editor View is created from the organ control dialog and is used to create and edit all anatomical structures. When the user selects an object, the object previously selected is deselected, i.e., the three lists act like a combined "radio menu". While working with contour editor, Curie Plan uses different types of cursors for different purposes.

The Special Cursor Types:



A. stdaddno.cur



B. cursor1.cur



C. cur001.cur



D. stdplusn.cur

Cursor A is used for adding new Node. Cursor B is a standard windows cursor. It is used for standard size of cursor. System cursor is not used, because user can change standard cursor type. Such changed cursor is not useful. Because, its size can be bigger. Cursor C is a node editing cursor. While moving a node, system uses this type of cursor. This cursor is XOR placed cursor. Therefore user can always see the drawing under the cursor. Cursor D gives information about editing a contour. While moving cursor (without pressing any button), if the cursor shape changes to this type, it means that a new node can be added to that portion of the contour.

Adding New Organ Contour and Creation Steps:

To add a new organ contour, user should place pointer to an empty area. And right click mouse to open Context menu. From context menu, "Add New Organ..." should be selected. A sub-pop-up menu appears on the screen that includes possible types of

organs. User selects new organ type from that menu. See Table 8.1 for predefined organ types and their densities.

Organ Contour Type	Electron Density Relative to H ₂ O
Body	0,991
Lung (inhale)	0,190
Lung (exhale)	0,459
Breast	0.976
Bone (dense)	1,512
Trabecular Bone	1,117
Liver	1,052
Muscle	1,043
Adipose	0,952

Table 8.1: Inhomogenitie values for various tissues

After selecting organ type, system waits mouse input from user to start drawing and creating organ contour. This mode has a Curser type A, a hatch shape and a small plus sign. Then user should select a beginning point on the coordinate space. Then, first node is started with left pointer click. While moving to second node, elastic line segment follows the pointer's hot spot. By clicking other nodes, contour is completed. To finish, a contour, user must double click the left button of the pointer.

Line segments must not be intersect with each other. If this is the case, some calculation kernels can produce wrong results. So user do not let any line intersections.

Editing a Contour:

First, user must select a contour by clicking left button of the pointer. To select a contour, inside of a contour or line segment must be pointed. But, some contours can cover others area. In this case, editor selects last created contour or top of the contour. After creation processes, orders of the contours can be changed. Details of such order change process are discussed in the next section.

Send Back and Send Front:

Normally, editor orders the contours into creation order. But, there is a problem occurs when user wants to select a small contour inside the bigger one. In such cases, small contour can not be selected. The solution is sending bigger contour to back. Therefore small contour can be easily selected by the user. Because, small contour becomes the higher order, editor selects nearest one. Send back and Send front menu items can be accessed from right click context menu. Before calling this function, contour must be selected.

Node Editing:

Node editing is a moving of the points, which are part of contour polylines. To start editing a node position, only one contour must be selected. If more than one contour is selected, only group selection commands can be used (e.g. group move and group

delete). Node can be inserted to connected line segments of the contour. Pointer cursor shape changes to D type where node insert is available. This is done by an algorithm of distance from a point to line segment calculation. If calculated value is smaller and equal then 2 pixels (screen pixel) this cursor shape is used. In the same way, cursor shape changes to cursor type C. In this state node position can be changed by the user.

Numerical values of the position, depth and organ type being edited can be watched from status line of the Curie Plan. These values are placed as a pane in the status line.

8.3. DIFFERENT Z-DEPTH MANAGEMENT

The organ control Box is controlling main flow of the program. It is used for creating and editing contours, specifying dose grid specifications and starting calculations.

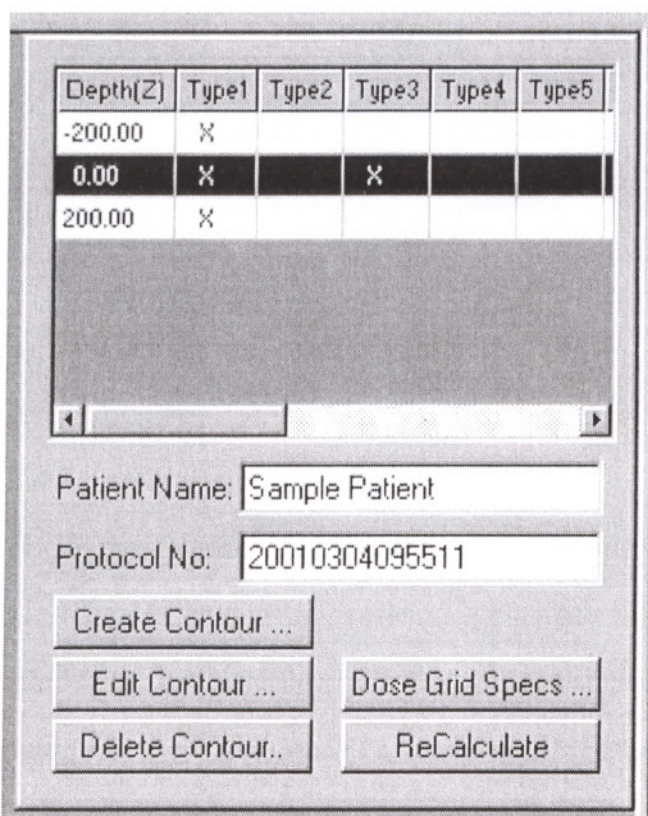


Figure 8.1: Organ Contour Selection Dialog Box

Main unique patient identification information is Patient Name and Protocol Number. Patient Name must be a string and Protocol No must be 14-digit number. For each depth, organ contents are shown with “X” sign. “X” sign shows presence of that organ existence in that depth. See figure 8.1.

Before editing a contour, user must select a depth from the list. If there is no selection, an error message will be displayed.

This dialog box is created by the application automatically, when a new patient file is created or opened from a disk file.

8.4. TREATMENT BEAM DEFINITION AND COUCH DIALOG

This dialog box lets users to specify beam and couch parameters for each field of Radiation therapy source or machine.

Field#: Field Type:

Field Name:

Field Attenuation Factor:

Collimator And Gantry Angles (degree)

Gantry Collim.

Rectangular Collimator (cm)

Left to Right to

Bottom to Top to

Couch Positioning (cm)

Angle Long.

Lateral Vertical

Select current Field

Create new field Delete current field

Figure 8.2: Field and Couch Parameters Dialog Box.

Field# is a non-editable field id number. When system creates a new template beam, a new id is assigned to that beam. This is the position of the beam in the beam list. Field type is an integer number. Field Name is a radiation treatment source or machine name. This field is 20 characters in length. Field Attenuation Factor is the effectiveness of that beam. Gantry and Collimator angles are specified in degree. Angle values are in the range of 0 to 360 degree. Minus sign is not supported. If user gives minus sign, results can include wrong results.

İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ
REKTÖRLÜĞÜ
Kütüphane ve Dokümantasyon Daire Bşk.

Rectangular Collimator sizes are defined with 4 floating point values. It is an important point that collimator size can be asymmetric.

Couch angle is a floating-point number between 0 and 360 degree. Other 3 positioning values are floating point numbers. And their dimensions are specified in cm.

8.5. 2D PLANER ISODOSE CURVE VISUALIZER

This view is used for visualizing isodose curves. When user creates a new document or open an existing one, it will be created automatically by the application. 5 levels of zoom factor can be used to both visualization and hardcopy for printers and plotters.

Zoom factor can be changed by using context menu (clicking right button of the pointer) in the isodose view area. User must be careful, defined zoom factor is affecting the hardcopy. Active zoom factor is grayed out (disabled) in the context menu.

User can easily place (pan) contents of the view by dragging pointer. While pressing left button of the pointer, moving pointer causes shifting whole drawing in the view.

8.6. 3D TREATMENT ROOM SIMULATION VIEW

A 3D room modeling is generated by the application. This room has mainly walls, machine base, and machine arm and machine table.

This view has a menu. This menu is different from main application menu. From menu, user can change some state of elements. For example wall drawing can be enabled or disabled. In this way, performance can be increased. Also some objects can not be observed because of others.

9. OBTAINED RESULTS AND EXAMPLES

9.1. RADIOTHERAPY PLANNING WITH MANUAL METHOD

Topography and Anatomic Measurements

Topographical measurements are very important for the radiation planning. Anatomic placement of the patient should be in the desired treatment position. Plaster cast strips, lead (solder) wire, flexible curves or other devices are combined with anatomic thickness measurements. Also, calipers are common methods for measuring topography.

Dose Prescription

Generally, it is desirable to have a uniform dose distribution within the target volume. A common and simplest way of dose prescription is calculation of absorbed dose at a given point (for example middle of the tumor may be calculated). This calculation is not enough. Isodose distribution curves must be drawn to minimize radiation absorption in normal healthy tissues. The isodose curves show the uniformity and nonuniformity of the beams, if the isodose drawing is prepared with manual method, steps of the procedures are as follows;

- First, patient contour is drawn on a transparent paper with 1/1 scale on a beam axial plane.
- Then, tumor volume, critical organ and tissue contours are drawn on this contour.
- A field or fields, which are used in the planning, are found from original isodose charts that appropriate field size.
- Sequentially, the isodose charts are placed on the contour with different angles and drawn to the transparent paper.
- Intersection points of the isodose lines are connected. After that, the lines that have equal doses are drawn; finally composite isodose curves are obtained.
- If more realistic isodose plans are required, correction for air gaps must be done. Because basic dose distribution data and isodose charts are obtained for flat surface, corrections are needed to dose distribution in actual patients. In manual planning, this correction can be done with isodose shifting. In this method, the isodose chart is moved down along a diverging ray by a fractional amount of the air gap. This fraction depends on the used energy of the beam.
- The field weighting is another way to find optimum dose distribution.
- If wedge filter is used, the isodose sheet must be wedge-filtered chart. Other procedures are same open (no filter) radiation fields.

An Example Of A Manual Radiotherapy Planning

In this example, a radiotherapy planning with manual method will be examined step by step. Preparation of the transparent open beam sheet, patient contour correction and summing up two beams will be discussed.

First, a transparent drawing of the beam's isodose sheet is obtained. Example of a 10MV photon beam with 10x10cm beam is shown in fig 9.1.

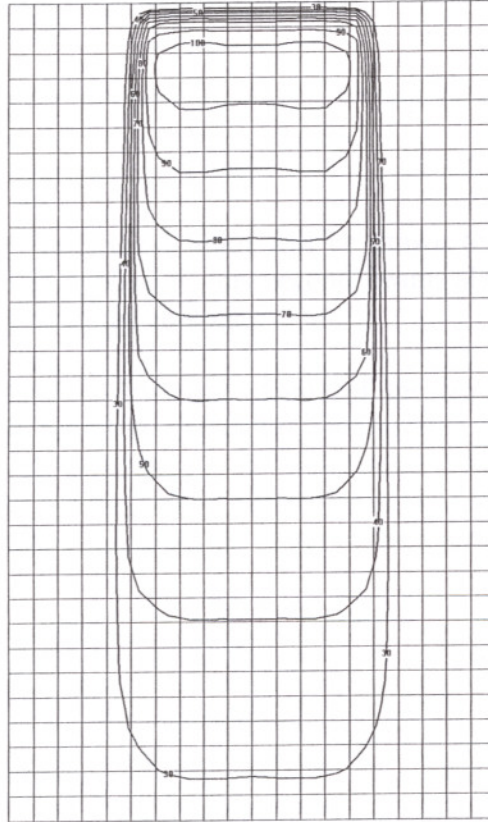


Figure 9.1: An example of a transparent isodose sheet for 10MV photon beam with 10x10cm collimator size at SSD = 100 cm.

Then, correction for contour irregularity correction is applied with shifting method. But this method is not accurate with compare to computer calculation methods. Because, computer calculations can be carried out by using similar triangles on the triangular prism. On the other hand, technicians can not apply such complex calculations or corrections to planning. In the manual planning, only perpendicular shifting can be applied to open beam to obtain contour correction. In the figure 9.2, contour corrected beam is shown.

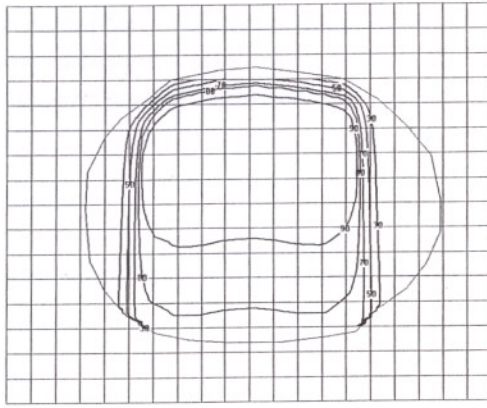


Figure 9.2: Beam with contour correction. Outer curve shows a leg contour.

After contour correction, the second beam will be drawn to a transparent sheet, too. Then, contour correction is applied to this second beam, also. But, the second beam position is at the bottom side of the contour.

Finally, summation is obtained by cross points of the iso lines of the beams. For example, new 100 line is found by connecting intersection points of the $10+90=100$, $20+80=100$, $30+70=100$, $40+60=100$, $50+50=100$, $60+40=100$, $70+30=100$, $80+20=100$ and $90+10=100$ lines (first number shows first beam iso line, and second number shows the second beam iso line). See figure 9.3 for result of the manual planning.

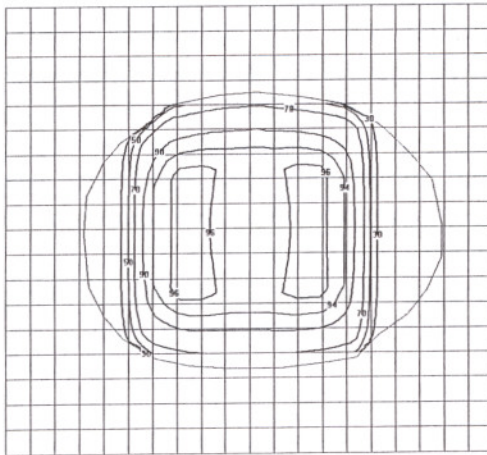


Figure 9.3: Composite isodose curves with two beams.

User can produce this simple manual planning in 40 minutes. For, different planning angles, additional 30 minute are required for each trial. In the average, a patient planning takes around 2 or 3 hours with manual planning.

Computer can make such calculation in 3 seconds (this time depends on CPU speed, in this example mobile PII-400 was used) after entering basic contour geometry. So very

short time is required for each plan. And more accurate results are obtained. As a result, technician can make many different planning in a very short time. So using computer planning can increase treatment quality significantly.

9.2. COMPARISON OF THE MANUAL AND COMPUTER PLANNING

Single Beam Manual Planning

Single beam is rarely used method. However, when the tumor is superficial, single beam treatment is preferred. The following criteria of acceptability may be used for a single field treatment.

1. The dose distribution within the tumor volume is reasonably uniform.
2. The maximum dose to the tissues in the beam is not excessive
3. Normal critical structures in the beam do not receive doses near or beyond tolerance

Multiple Beam Manual Planning

For treatment of most tumors, however, a combination of two or more beam is required for an acceptable distribution of dose within the tumor and surrounding normal tissues. First patient contour are drawn. Then using field numbers, field angles and field sizes determined. Then appropriate field size custom isodose charts placed on the contour together. And crossing points are found. And by connecting these points with the line segments, isodose curves are obtained. Sometimes contour irregularities and inhomogeneity corrections are done manually. They are not applied always, because, they takes long times. Also these methods cause bigger calculation errors. The procedures thereafter repeated various field numbers, sizes, weights and angles to find optimum dose distribution. These procedures are time consuming (for a one patient approximately two hours) and erroneous.

Computer has speed and accuracy advantage over manual planning. It allows the users to compare many different situations at the same patient data. Patient data entering is takes long time with compared to calculation times. But in manual planning, calculations take long time. So in the manual method, different field cases can not be calculated.

9.3. PRODUCED PATIENT PLANNING EXAMPLES

The Curie plan has been applied to the actual treatments at “Özel Ege Onkoloji Radyoterapi kliniği” for 11 patients with some restrictions because of data deficiencies.

For 11 patients, 10X10 cm. Co-60 therapy field sizes are used. OAR's are measured with film dosimetry method for this field size as described Appendix 1. PDD, TMR and SPR values are taken from machine vendor for the reference field size.

For those 11 patients, also all planning procedures are done with old manual system. Obtained Results are:

1. Comparing the manual drawn composite isodose with Curie plan isodoses are suit each other with high ratio (maximum deviation is about $\pm 2\%$). This variation has small effect on the calculations. Because, the maximum variation has been occurred at the corners of the fields.
2. Manuel procedure took 185 minutes for one patient, for curie plan 32 minutes. In future, when physics and technicians will adapt the software, this time will be decreased.
3. Clinicians can test different plans easily and short times with Curie plan.
4. If the clinic has all of the beam data, the Curie plan will work completely for all patients.

10. CONCLUSION AND THE FEATURE WORKS

The main aim of this project, which is a base of a Radiotherapy planning software, which can be run with desired performance on a low cost PC hardware, has been achieved. In order to be realistic about the exact needs, this software has been tested for 3 months by "Özel Ege Onkoloji Radyoterapi kliniği". Also with the feedbacks from the persons of the center, some deficiencies have been completed. This center has two Co-60 units and an ATC simulator. Before testing this software, the center was doing the calculations manually or a conventional planning system. The first test results indicate that, system is suitable for Co-60 external radiotherapy planning requirements since the application of alternative setup techniques. These techniques include alternative gantry, couch and collimator angles, alternative field sizes, field weights and field numbers.

With this program, the isodose curves at different depths can be observed by the user. Since this system works on a PC based computers and peripherals and program is written in Turkey, it is easy to translate to Turkish and do some modifications according to the user needs. Modification of the program, according to special requests of the clinics in Turkey, indicates this advantage.

The program can be easily adapted to various radiotherapy machines and imaging systems such as fully computer controlled sophisticated R.T. machines and digital imaging systems. Another advantage of this program is that the user can easily get service directly from the programmer.

The future development steps may be as follows:

1. Least for three depths, 50 depth ratios and 15-20 field sizes and various energies
2. Measure OAR's.
3. Adaptation to multileaf collimator equipped machines. Block calculations and
4. Irregular field calculations can be added to this project.
5. For 3D CRT planning, beam's eye view option can be added.
6. Planning system and new algorithms for proton and neutron radiotherapy.

Several new radiotherapy techniques are developed in the last ten years, such as multileaf collimator equipped machines, 3D conformal radiotherapy Intensity Modulated Radiotherapy (IMRT) and Radiotherapy machines that use high energy subatomic particles (proton, neutron) and heavy ions. These new techniques will be applicable in Turkey as well in the near future. Therefore radiotherapy planning systems should be adaptable to these new techniques.

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APPENDIX

Developed Calculation And OAR Method With Film Dosimetry

Introduction

All radiotherapy planning systems use dose profile data. There are various methods to measure dose profiles. They are using an ionization chamber detector in water phantom, thermoluminescent dosimeters, radiographic or radiochromic films, light detectors and semiconductor detectors. All of these methods have some advantages and disadvantages. In this work we use ordinary radiographic films and special port films to measure dose profiles (and OAR values).

Materials and Methods

Dose profiles (or OAR values) depend on a scanned dose measurements perpendicular to the central axis, across a beam. Dose profiles are normally made at several depths of interest (least three levels). Figure A-1 shows a dose profile.

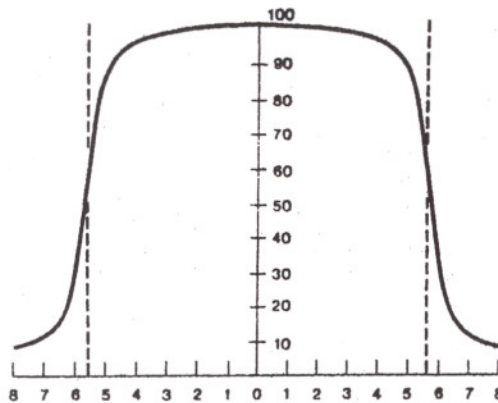


Figure A-1: Measured depth dose profile showing variation of dose across the field. SSD = 80 cm, depth = 20cm. Dotted line indicates geometric field boundary.

OAR is off-axis ratio that indicates variation in dose with several distances from the central axis at same depth. OAR's can be directly measured by several methods or extracted from dose profile graphics.

These measurements have done with a film dosimetry system. Two film categories are used.

1. Kodak radiography film.
2. Kodak radiation therapy verification film.

Measurements are done three or more depths of solid phantom material. For example, these depths can be 5, 10, 15 centimeters. First of all, film places tightly to phantom and perpendicular to the central axis of the beam. The film edge is carefully aligned with the phantom plate surface and air pockets between the film surface and the surrounding jacket.

Then the films are scanned. Optical densities are measured in equal ratio distances from the central axis. Optical densities are correlated by using a depth dependent sensitometric curve. Raw data obtained from the film is shown in the figure A-2.

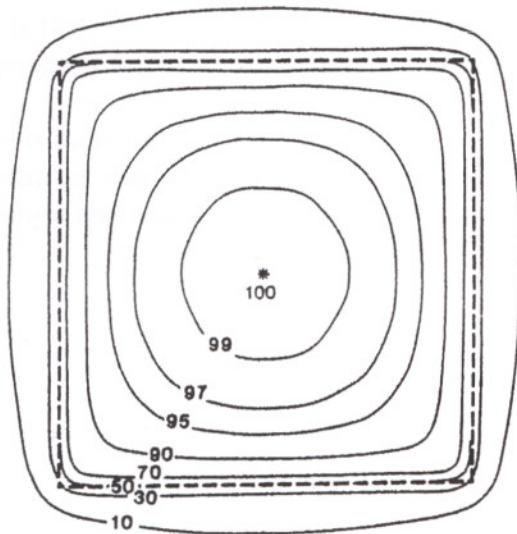


Figure A-2: Cross-sectional isodose distribution in a plane perpendicular to the central axis of the beam. Isodose values are normalized to 100% at the center of the field.

A plot of net optical density as a function of radiation exposure or dose is termed the sensitometric curves are derived from known central axis depth dose data for a reference field size (10X10 cm).

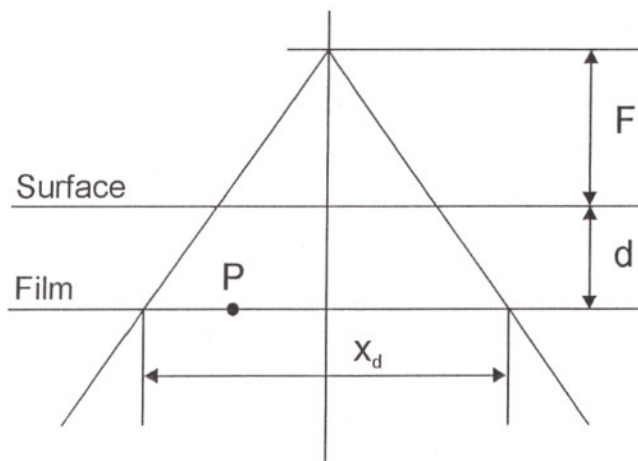


Figure A-3: Film dosimetry setup.

The measurement setup is shown in the figure A-3. And parameter explanations are defined as bellow:

- F: Source to isocenter (or any reference point) distance.
- d: Depth of interested point P
- P: Interested point.
- Xd: Projected field size at d depth.
- Yd: Lateral distance from central axis.

At each depth and each field sizes, Yd, OCR's are measured at the same series of beam width ratios $2Yd/Xd$.

The smallest value is D, D that represents the beam central axis.

A value of I, O represents the beam edge and a value greater than I, O represents past the field edge.

Sensitometric curve is more linear for a port film.

Isodose charts are drawn with the profile data which derivation of explained above, compared with original isodose chart which given by the manufacturer isodose charts.

Results

In this work films are taken three depths, maximum 50 field width ratios and 10 field sizes (from 6X6 to 30X30 cm) for Cobalt-60 teletherapy units.

Optical densities are correlated with derived sensitometric curves. And thereafter isodose charts are drawn for some field sizes with using these data and a computer program, which use type of data.

For the cobalt-60 source, film has been found to measure profiles with acceptable accuracy ($\pm 2\%$).

Conclusion

A radiological film consists of a transparent film base (cellulose acetate or polyester resin) coated with an emulsion containing very small crystals of silver bromide. When the film is exposed to ionizing radiation the crystals are affected. When the film is developed, the crystals are reduced to metallic silver. The film is then fixed. The unaffected silver bromide is removed from the fixer. The metallic silver, which is not affected causes darkening of the film. Thus the degree (optical density) of the film depends on the radiation energy absorbed.

But optical density is not change linearly with radiation dose. It varies one kind film to another. Therefore a sensitometric curve must be drawn.

Second important procedure is determining the net optical density, which is obtained by subtracting the reading for the base fog from the measured optical density. Calibration of scanner, fixing apparatus and chemical quality, using of same kind films are important issues also, to decrease errors.