CLINICAL PHOTON BEAM TREATMENT PLANNING USING CONVOLUTION AND SUPERPOSITION

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The goal of this research project is to improve photon treatment planning algorithms based on convolution and superposition.

Monte Carlo generated absorbed dose deposition kernels were computed for materials frequently encountered in radiotherapy, such as water, tissue, bone, calcium, iron, copper and muscle. For a monoenergetic parallel photon beam impinging upon a homogeneous water phantom, the absorbed dose can be calculated as a convolution of the absorbed dose deposition kernel for that energy and the Total Energy Released per unit Mass (TERMA). When a more realistic diverging, polyenergetic beam is considered impinging on a homogeneous water phantom, we have shown that a single polyenergetic kernel can be used where the beam hardening and the divergence of the dose kernels (kernel tilting) are accounted for.

The concept of Secondary Radiation Equilibrium (SRE) was introduced as a method of reducing the computation time for the convolution calculation by segmenting the TERMA into slowly varying regions and then radially integrating the kernels to yield cumulative absorbed dose deposition kernels. It was shown that the cumulative kernels can be used in an unique way to yield a new expression of Burlin's cavity theory.

The superposition algorithm is essentially a convolution in radiological space (distance has units of gr/cm2 instead of cm). It was conceived as an adequate approximation to compute absorbed dose in inhomogeneous media that are water equivalent. The distance is scaled based on the material density, thus accounting to some extent for changes in absorbed dose deposition. When scaled water kernels are used, absorbed dose predictions are close to measured data for media with atomic number close to that of water, but differ noticeably when high Z materials are encountered.

With the inclusion of absorbed dose deposition kernels for media with different atomic numbers, we extended the superposition equation to explicitly account for changes in charged particle scatter and more closely predict the absorbed dose in inhomogeneous media, even under conditions of electronic disequilibrium. The same methodology applies to cavity theories, where unlike the traditional Burlin approach, the convolution method can provide a absorbed dose distribution in the cavity rather than just a mean value.

The concept of ``the extended phantom'' was also explored, where the patient as well as the beam, beam modifiers, and the portal imaging device are included in the convolution absorbed dose calculation, thus accounting for any form of scattering.

Finally the convolution code was used to obtain and study output factors from clinical linear accelerators. The phantom-generated output factors were calculated using convolution, the total output factor was obtained from measurements, and the collimator-generated output factor was calculated as the ratio of the two. With the inclusion of machine head in the convolution calculation (extended phantom), the machine-generated component could be computed solely from convolution. A new unit of energy fluence per monitor unit was introduced for computing monitor units in clinical treatments for convolution based treatment planning algorithms.