Small Animal Research Platform

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System Backgrounds

Computed Tomography

-X-ray CT allows for imaging of internal body structures
-Image can be reconstructed using filtered back projection
-Data acquired from projections at different angles
-Good contrast between different tissue density
-X-rays projected into the body and scattered
-Can be used to obtain 2D and 3D images
Hardware components:
- -Cu/Al Filters
- -Lead leaves (X-ray focus)
- -Collimator
- -Scintillator Crystals
- -Photomultiplier Tubes

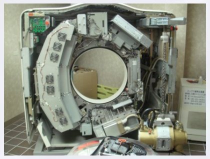

Figure 1: The internal components of an x-ray CT machine. T: the x-ray tube. X: the x-rays produced that travel through the patient. D: the detector array. R: direction of gantry rotation. Ref: [http://en.wikipedia.org/wiki/File:Ct-internals.jpg]

Positron Emission Tomography

-Allows imaging of internal bodily functions
-Used to obtain 2D and 3D images
-Radionuclide decays by positron emission
-Positron and electron collide, producing gamma rays
-Data acquired from gamma rays in a detector ring
-Image can be reconstructed using filtered back projection
Hardware components:
- -Scintillator Crystals
- -Photomultiplier Tubes

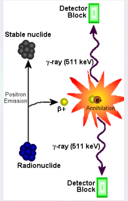

Figure 2: The basics of PET data collection

Radiation Therapy

-Uses ionizing radiation to kill unwanted cells
-Tumor shape/location are determined from CT images
-IMRT (intensity modulated radiation therapy) used to maximize absorbed dose and accuracy
- Beam shaped to tumor with multi-leaf collimator
Hardware components:
- -High energy linear accelerator
- -Collimator
- -Dosimeter
- -Cooling system

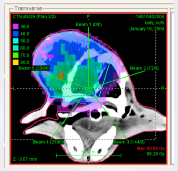

Figure 3: An IMRT plan showing the exact location and size of the radiation beams. Ref: [http://www.rr-research.no/olsen/]

Motivation for Combined Systems

-Several RT/CT and CT/PET systems currently exist
-Images from different systems can be superimposed to correlate respective information
- -CT scan shows anatomy, PET scan shows metabolic activity
- -Resulting images allow areas of targeted metabolic activity to be accurately located

-Can use information to formulate most effective treatment plan

Open Source Medical Devices

-Provides free access to all design specifications
-Encourages collaboration amongst researchers
-Allows inexpensive research equipment and technology
-Design can be customized to fit clients' needs

Abstract

Open source medical devices allow researchers to collaborate and access relatively inexpensive equipment. A combined computer tomography (CT), positron emission tomography (PET) and radiation therapy (RT) system is being developed in the spirit of open source technology. The combination of these systems has the added benefit of correlating data among the imaging systems and using this data for precise radiation therapy treatment. The CT system uses X-ray radiation and detectors to produce 2-D and 3-D cross-sectional images of anatomical structures at high resolution. The PET system uses radioactive tracers to highlight metabolic activity of different biological structures. The RT system uses high intensity X-ray radiation to non-invasively obliterate cancerous cells in the body. A table of specifications for various components of the different systems has been developed with the intention of designing a combined system with the minimal number of components. SolidWorks graphics are being developed in order to simulate heat transfer, download parts from vendors, assess compatibility, and aid in rapid prototyping.

Customer Requirements

Customer Requirements describe what the customer and how the product will serve those needs. This covers the customers' expectations for the product.
Potential Customers:
- -Physicians
- -Radiologists
- -Oncology researchers
- -Medical physicists
- -Pharmaceutical researchers

Significant Requirements:
- -Easy to construct
- -Include hardware that is easily available for purchase
- -Options to choose quality of parts based on cost
- -Modular systems
- -High resolution imaging
- -Approved by FDA and AVMA regulations
- -Safety
- -Able to complete successive scans and therapy as needed

Figure 4 – Cartoon of a physician using a CT machine. Ref: [http://www.cancerquest.org/images/ct.jpg]

Design and Construction Plan

-All design on the project will be open source
-Determine systems involved and define specifications for them
-Find vendors and catalog all parts that are compatible with this design
-Assemble a model on SolidWorks
-Test parts using physics simulations in SolidWorks
-Release a list of all parts that meet the safety and design specifications
-Anyone can purchase parts and build the machine
-Can buy machine fully assembled at a small fee
-Work with clients to design custom machines if necessary

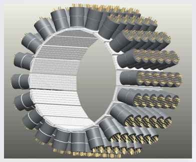

Figure 6 – SolidWorks drawing of a PET detector block.

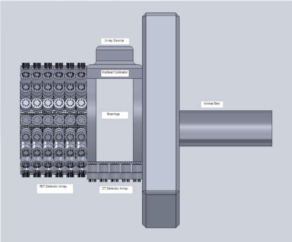

Figure 5 – SolidWorks design (top view) with parts labeled.

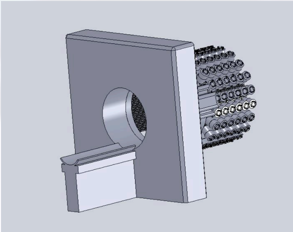

Figure 6 – SolidWorks design (isometric view) showing the various components.

Engineering Requirements

Computed Tomography

Item	Details
X-ray Source Energy	50-100 kVp
Focal Spot	< 10 microns
Filters	0.5 mm Cu and 1 mm Al
Acquisition Geometry	Fan Beam
Detector	Silicon Photodiodes
Detector Resolution	20-40 micron, 0.25 mm^3 voxel resolution

Positron Emission Tomography

Item	Details
Scintillation Crystals	LSO; 10mm thick
Photomultiplier Tube (PMT)	Gain: 1.7E6; 19mm diameter
Timing Resolution	312 ps
Image Reconstruction	Filter-back projection
Radioisotopes	Co-57

Radiation Therapy

Item	Details
Orthovoltage Tube	250 kVp max
Focal Spots	0.4 mm
Dosimeter (ion chamber)	3 mm radius; 317 x 107 Gy/C
Collimator	2 mm thick; 120 leaves

Combined System

Item	Details
Couch System	0.125 mm; 0.05° rotational
Bore Diameter	12 cm
Cooling System	Air cooling
Beam Shielding System	Pb shielding
Physical Platform	Made from plastics
Treatment Planning system	Wisc Plan

Future Work

-Build model on SolidWorks for physics simulation and rapid prototyping
-Run simulation to determine radiation shielding and cooling methods
-Design custom parts that cannot be bought so they can accommodate manufactured parts
-Using the rapid prototyping machine in the Morgridge Institute, create a plastic 3-D prototype
-Develop and open source software package

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