Digital Beam Attenuator (Beam Attenuator)

Project Design Specifications
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Problem Statement:

In X-Ray Computed Tomography, a uniform X-Ray beam is used despite the fact that the transmission though the patient varies significantly due to the patient's anatomy. For almost any clinical or proposed medical x-ray imaging system, either a proposal for intensity modulation (IM) exists in literature or a form of IM is implemented clinically, but these forms of IM are limited in that they cannot adapt the incident photon flux over time to match all projections. The use of a uniform X-Ray incident beam results in a non-uniform signal-to-noise ratio, a sub-optimal distribution of X-Ray scatter, and significantly higher or lower dose than necessary to some regions of the body. Since current devices are only able to statically attenuate the X-Ray beam, we propose to design and actuate a series of dynamically attenuating wedge pairs placed between the X-Ray source and the patient. The attenuating wedges will use the changing thickness of the wedge pairs to locally attenuate the incident beam, which will result in improved image quality and reduced X-Ray dosages.

Client Requirements:

- A new prototype shall be designed and manufactured.
- The system shall linearly actuate the prototype.
- The wedges of the prototype shall move in response to pre-programmed positions.
- The wedges of the prototype shall move independently.

1. Physical and Operational Characteristics

A. **Performance requirements**: The device shall alter the strength of the X-Ray beam as a function of position for the duration of the Computed Tomography (CT) scan. The device must move at a minimum speed of 15 mm/s. The prototype must actuate the wedges to satisfy a dynamic range that encompasses the entire X-Ray beam.
B. **Safety**: The prototype must not be harmful to the researcher, user, or patient. The prototype must not harm the machine or interfere with its intended operation. It also must be self-contained during the duration of the scan.
C. **Accuracy and Reliability**: The actuator must be able to move the wedges within 1 mm of accuracy.
D. **Life in Service**: The device will be a prototype and thus has a limited life in service. The device shall have a life in service of one year of frequent use. If implemented clinically, the device must have a life in service equal to that of the CT scanner.

E. **Operating Environment**: The prototype is to be used by graduate students and professors in a CT research lab. During testing, the device will be exposed to X-Ray radiation; therefore, design components must be resistant to X-Ray damage.
F. **Ergonomics**: There are no ergonomic concerns relating to the prototype.
G. **Size**: The prototype shall be as small as possible while maintaining full functionality. It must be large enough to attenuate the X-Ray beam throughout the entire dynamic range at a minimum of 31.75 cm from the X-Ray point source.
H. **Weight**: The prototype shall be as lightweight as possible while maintaining an appropriate level of X-Ray attenuation.
I. **Materials**: All parts shall be resistant to damage by X-Ray radiation. The wedge material shall be homogeneous in order to uniformly transmit X-Rays and correctly attenuate the X-Ray beams. It shall also slide with a low coefficient of friction.
J. **Aesthetics, Appearance, and Finish**: The device is a prototype and therefore functionality is the dominant consideration over aesthetics and appearance.

2. Production Characteristics

A. **Quantity**: One prototype shall be produced.
B. **Target Product Cost**: The budget for this semester is $5,000.

3. Miscellaneous

A. **Standards and Specifications**: The final product will require the approval of the Food and Drug Administration and clinical trials. The prototype is a proof of concept, and therefore will not require government approval.
B. **Customer**: The intended user is a medical professional or researcher who will utilize Digital Beam Attenuation to improve CT image quality during a medical procedure or for diagnostic purposes.
C. **Patient-related Concerns**: As our design may eventually be commercially available for medical professional use, it should follow all restrictions enforced by the Food and Drug Administration. It must not cause any harm to its user.
D. **Competition**: No other forms of Digital Beam Attenuation exist at this time. Statistical CT Image Reconstruction is also being used to create better quality CT images, but that technology is currently in development. In addition, static devices like bowtie filters are currently being used to attenuate X-Ray beams on CT scanners.