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Interventional X-ray quality measure based on a psychovisual detectability model

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Rationale

Classical estimates of diagnostic performance – model observers – typically test subtle signals at threshold contrast perception. This approach may not be suitable for real-time quality assessment of medical imaging systems in which observers operate at suprathreshold contrast levels, such as interventional X-ray. Automatic dose control mechanisms for these systems adjust patient dose based on pre-determined patient thickness/dose curves and measurement of average gray levels in the acquisition [1], and may overestimate the dose needed to conduct the clinical task on a given patient or region. We present a real-time task-based quality measure that aims to estimate the minimum dose needed to obtain suprathreshold contrasts of target objects (vessels). This measure may be incorporated in a feedback loop for dose reduction while ensuring sufficient image quality for the clinical task.

Methods

The quality measure was built from two components: (1) a detectability function which models the clinical task of target detection, consisting of a set of psychometric functions that predict the detectability of vessel-like targets given a set of image features such as contrast and noise [2], and (2) an algorithm which measures these features on X-ray sequences. The psychometric functions were two-parameter psychometric Weibull functions fit to 1-down/1-up staircase results. Image parameters were varied to represent realistic image content as measured on interventional X-ray phantom and patient images. Background parameters were varied to correspond to changes in dose level: two levels of additive uncorrelated Gaussian noise including a noise-free background, and four background luminance levels. Sloan letters were used as targets. Test images were presented with static (still) and dynamic (25 frames per second) noise. The second component was an algorithm that estimated image features such as target contrast [3], background luminance, and noise variance. The detectability (0 to 100%) of image pixels was determined from the corresponding psychometric functions, given the measured image feature values. The quality measure was defined as the ratio of pixels with 100% detectability to the total number of detectable pixels. The change in contrast or noise, corresponding to a change in dose, needed to reach 99.5% detectability was also determined. The quality model was compared to a subjective quality study conducted on a chest phantom with contrast-filled cardiac arteries acquired at 12 dose levels on a Philips Allura interventional X-ray system.

Results

Preliminary results indicate that the model has a monotonic relationship with subjective quality preferences of interventional cardiologists. Further experiments are currently in progress.

Conclusions

We present an image quality measure which may be used in a real-time interventional X-ray dose control loop. While initial results are promising, further research is needed to validate the approach.

References

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