Assessment of task-based image quality for abdominal CT protocols based on mathematical model observers

Topic:	Calibration of CT scanners through image analysis
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1. Problem Definition

In medicine, the use of ionizing radiation for diagnostic and therapeutic procedures plays a major role in patient care and safety. However, during examinations patients are exposed to potentially harmful radiation, with computed tomography (CT) being responsible for some of the highest doses. Therefore, manufacturers and users of CT have been devoting considerable efforts to reduce the dose per examination with the integration of new technologies and the optimization of clinical protocols. Nevertheless, changing the radiation dose of a clinical protocol without assessing the image quality is suboptimal. With older CT scanners an excessive dose reduction could lead to variations in image quality and patient care. This could be problematic, as the goal is the standardization of image quality so that it is still sufficient for the clinical task at the lowest possible dose.

The goal of this thesis is to develop and validate a platform for scoring CT image quality based on an anthropomorphic mathematical model observer. CT images are provided by the Luzerner Kantonsspital (LUKS) and correspond to various locations within the hospital region of the LUKS. The task we consider is the detection of low contrast lesions within a section of the phantom. The low contrast module, which is inserted into a phantom, contains lesions of different diameters and contrasts. A different module without lesions is used to extract the background signal. A total of five different dose configurations (4mGy, 8mGy, 10mGy, 15mGy, 20mGy) for the CT scanners are considered. In the end, the datasets will be evaluated using the platform.

2. Solution Concept

The platform is implemented in Python and divided into two components. The first component pre-processes the images and reduces the noise by applying Gaussian and Median blur filters. Subsequently, the region of interest (ROI) is extracted using a Hough Transform and the corresponding lesion sizes are found by using information from a configuration file as well as knowledge about the used module. Lesions of identical size and contrast from one dose are stored in the same folder. The second component takes a set of signal images, in this case of approximately 70, and their corresponding background ROI images as input and scores the image quality using a Channelized Hoteling Observer with 10 Dense Difference of Gaussian (DDoG) channels. It returns an estimate of the detectability (d') and the proportion correct (PC) which is the fraction of correctly classified images. The two figures of merit are obtained by using the bootstrap technique with 1000 trails.

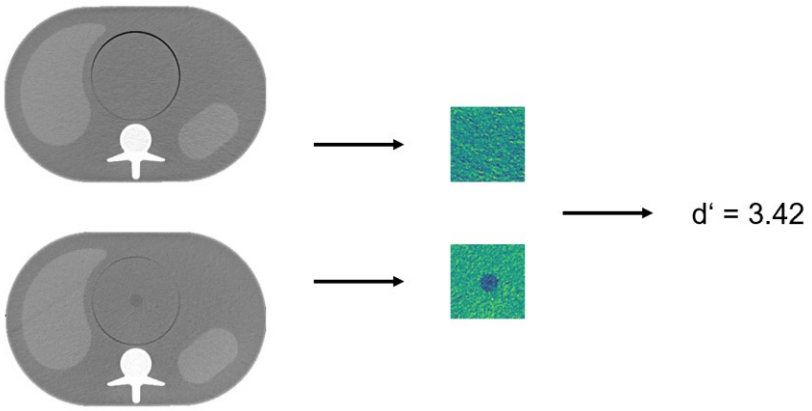

Figure 1: Simplified workflow from original image to d’

3. Special Challenges

As the dose decreases, the structures and lesions become less visible in the images. For this reason, the automatic determination of lesion sizes was not reliable at low dosage, even if the implemented approach worked well for high doses. This repeatedly gave rise to challenges that had to be overcome, especially with the appropriate pre-processing of the images and the combination of different approaches. Furthermore, the thesis can be classified thematically in an area between medicine, physics, and computer science. A good understanding of all three disciplines and their integration are required for a successful outcome. This constitutes a rather high entry barrier for the project.

4. Results

As a result of this thesis, an implemented and validated platform is available, which assesses the image quality of CT images from a standard phantom. The results are presented textually but also graphically so that the user has quick overview.

The evaluation of the provided datasets shows that d’ drops with decreasing dose. In addition, the standard deviation tends to be slightly larger at higher doses than at low doses. For the evaluation in Fig. 2 a ROI size of 50x50 pixels and a lesion size of 5mm with 30 HU was used. For other lesion sizes, the results can vary, but are comparable in their significance. The dispersion is considerable on both axes. The deviations on the x-axis are due to the fact that in most cases the CT scanners use a slightly higher dose than set by the user. Within a dose, d’ differs among devices, although the range of dispersion between the different doses is about the same. In addition, the performance of some devices is constantly better, while others have relatively strong fluctuations. In Fig. 2, the resulting PC is almost consistently 1 with a minimal variation for one device at a low dose. This means that close to all images with this lesion size are classified correctly for all used doses. In general, the PC is worse for smaller lesion sizes than for bigger lesion sizes. In summary, the evaluation shows clearly that a general dose reduction would massively endanger patient safety, as the CT scanners have very different performances. Consequently, it must be evaluated individually for each device type and setting of the device how much the dose can be reduced.

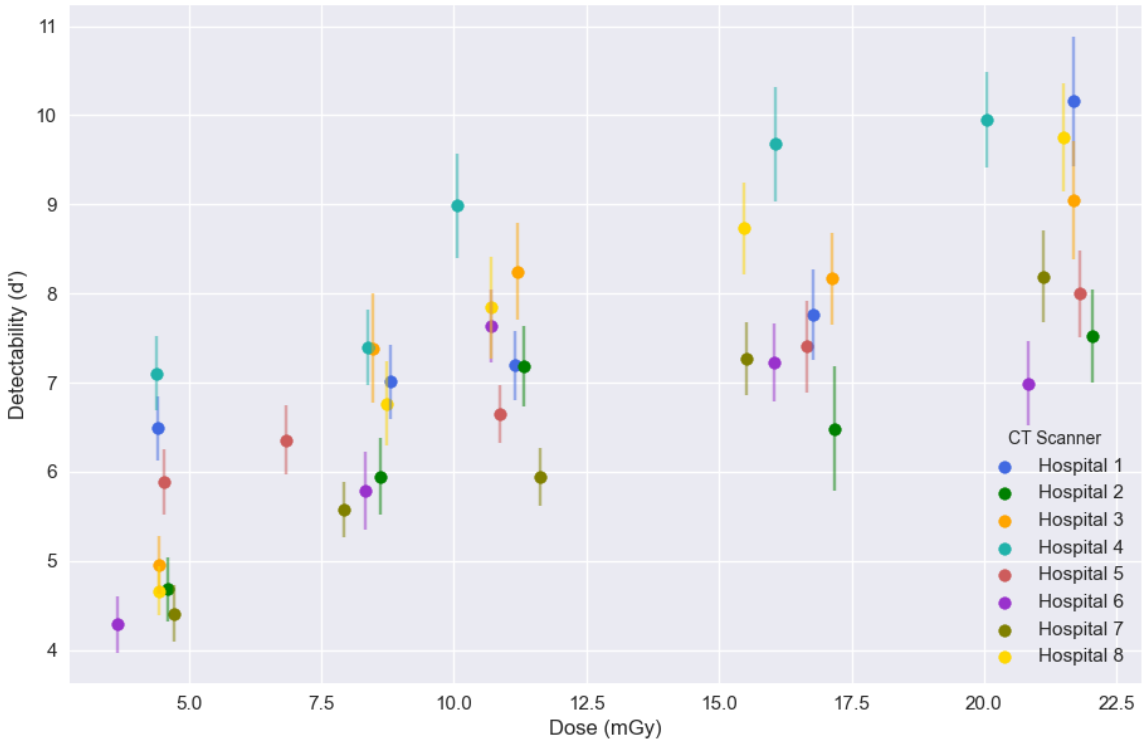

Figure 2: Detectability of lesion (5mm 30HU) for 4mGy, 8mGy, 10mGy, 15mGy and 20mGy

5. Outlook

The implemented platform delivers good results and is able to reliably evaluate the data sets. Two aspects are of great interest for follow-up projects. On the one hand, the additional implementation of a human observer would be an interesting task to tackle. On the other hand, further development of the lesion size detection would be of great interest. The aim could be to ensure that the used module in the phantom has no influence on the calibration procedure, and this could be achieved for instance using supervised learning.