BOTTLENECKS IN VALIDATION OF ALGORITHMS FOR PERFUSION IMAGE PROCESSING

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Abstract. *Validation of algorithms for perfusion image processing allows its inner features to be highlighted, as well as evaluation of its pros and cons. This study provides an overview of the current state of the field of algorithm validation for perfusion image processing. It defines the bottlenecks in the process of comparison of algorithm results to the ground truth.*

Keywords: image processing; algorithm validation; gold standard; perfusion.

PURPOSE

Computed tomography (CT) and magnetic resonance (MR) first-pass perfusion imaging undergoes fast technical progress in recent years. Despite the fact that it has been proven the potential of perfusion imaging to improve evaluation of cerebrovascular diseases or tumour angiogenesis, its clinical use is still limited [1, 2]. Partially it can be explained by necessity to provide manual processing of a large amount of patient images. This process is extremely tedious, time-consuming, and influenced by operator bias. The advent of semi- and fully automatic algorithms for perfusion image processing led to reduction of time losses and errors due to operator bias [3, 4].

Recently, a variety of algorithms for CT and MR perfusion image processing available from imaging unit manufacturers, third-party vendors, and academic groups [5]. Despite this fact, the improvement of available algorithms still remains as well as the development of new ones. This validation of perfusion image processing algorithms is important in view of practical diagnosis purposes, comparing results among studies, and use perfusion imaging as a criterion of patient selection for clinical trials. The proper validation is also important to know which algorithm performs best on the data and play significant role for steps on its improvement.

The purpose of this study is to provide an overview of the current state of the field of algorithm validation for perfusion image processing and define the bottlenecks in this process.

VALIDATION OF PERFUSION IMAGE PROCESSIGN

Common evaluation of image processing allows describing any algorithm in a generic and standardized style from the main characteristics of its steps.

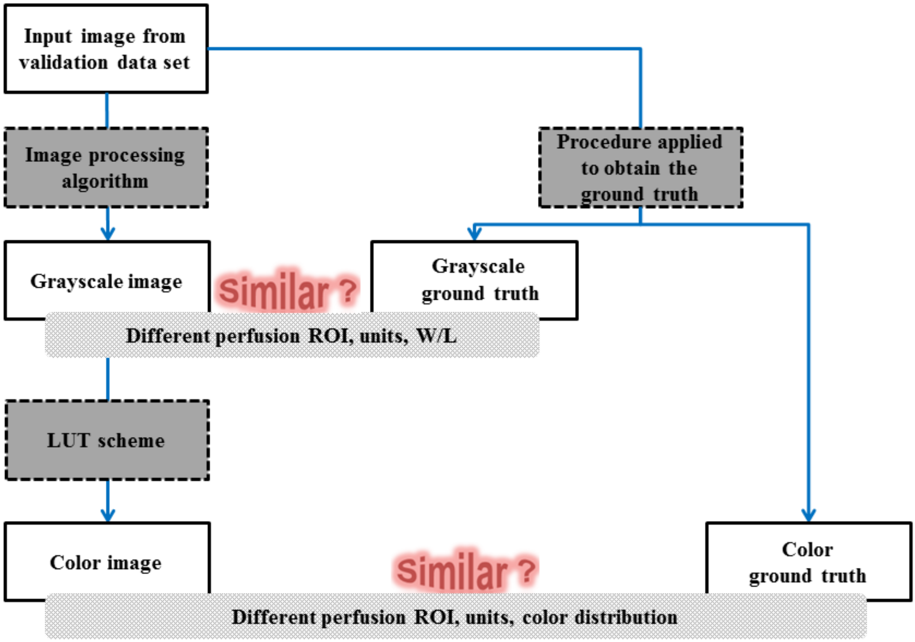

Figure 1: Possible bottlenecks in the validation of algorithms for perfusion image processing.

Therefore, validation of perfusion image processing could be characterized by its component steps [1, 2]:

(1) motion correction,

(2) spatial and temporal smoothing,

(3) registration,

(4) definition of the perfusion region of interest (ROI),

(5) calculation of pixel-wise concentration-time curves,

(6) quantification of different hemodynamic parameters on a pixel-by-pixel basis,

(7) applying a look-up table (LUT) scheme and window/level (W/L) operations to generate color-coded perfusion maps,

(8) results visualization in 2D/3D space.

Validation of each of the mentioned above components relates to the steps that provide the measurement of their efficiency and accuracy. These steps generally refer to the design of validation data set and definition of validation criterion.

Validation requires algorithm execution on a large set of images, which should contain positive, false positive, negative, and false negative cases. All of these cases represent a validation data set, which is used as input by the algorithm to be validated and by the procedure applied to obtain the ground truth. Based on the specificity of validation process used in the study, the ground truth may be known (e.g. when it is obtained from numerical simulations or realistic simulations from clinical images), or it may be computed (e.g. when using physical phantoms or clinical images especially collected for validation purposes), or it may be given as reference (e.g. when it is defined by experienced radiologist(s) using clinical images obtained from clinical routine). Therefore, even using ground truth may lead to some uncertainties that should be considered within the validation process.

The validation criterion allows the results of the algorithm to be compared to the ground truth. It should define validation metrics and corresponding mathematical or statistical tools have to be used to provide comparison. Validation metrics should be carefully defined as measures of agreement (or disagreement) between results of the algorithm and ground truth, and they should not represent invalid measurements. Assessment of the comparison results provides final result of the algorithm validation.

Key issue of any validation is clear identification of the context and adaption of the validation process to the problem to be resolved. The output of each of the mentioned above components of perfusion image processing is images. Therefore, the comparison should operate with such measures as image similarity. Consequently, validation metrics should properly indicate how well one image corresponds to another one. Appropriate choice of validation metrics is challenging and may depend on many criteria. Schematic presentation possible bottlenecks in validation of algorithms for perfu-sion image processing can be found in Figure 1.

It should be mentioned that the validation process of algorithms for perfusion image processing may be performed without ground truth data (e.g. for studying robustness or accuracy of particular component of already available algorithm).

CONCLUSION

Validation of algorithms for perfusion image processing should be based on the appropriate design of validation data set and careful definition of validation criterion. Without standardization process in this field it remains difficult to provide a comparison of the performance of different processing algorithms and, some-times, even to understand the results of the conducted study.

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