DCE-MRI-oriented Volume Rendering for Monitoring of Crohn's Disease

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1 Introduction

Inflammatory bowel diseases (IBD) constitute one of the largest health care problems in the Western World, affecting over 1 million European citizens alone, 700,000 of who suffer from Crohn's disease (CD). Grading of CD severity is important to determine treatment strategy and to quantify the response to treatment. Colonoscopy in combination with the assessment of biopsy samples is considered the reference standard for diagnosis of all IBD. However, the procedure is invasive and requires extensive bowel preparation, which is considered very burdensome by most patients. Moreover, it only gives information on superficial abnormalities.

The project VIGOR++, in which the presented research is performed, among other goals, aims to create a non-invasive procedure for improved CD monitoring and accurate grading of CD severity. The non-invasiveness will be achieved by focusing the monitoring on magnetic resonance imaging (MRI). Effectively, this would render the standard methods (colonoscopy/biopsy) superfluous.

In this paper we present a specially tailored volumetric visualization for the acquired MRI data. The aim is to provide the physicians with an alternative to reviewing all slices of the data separately. To be able to highlight the features important for the monitoring of Crohn's disease, we employ dynamic-contrast enhanced MRI (DCE-MRI) data. The interesting features exhibit specific changes of the measured intensity over time (time-intensity curves, TICs). We determine for each position how good the local TIC resembles a typical curve of inflamed tissue using a derived parameter we call *normalized integral*. The result is then used to emphasize those locations in the volumetric visualization.

2 Data

All data has been acquired using a Philips Intera 3 Tesla scanner at AMC Amsterdam. 450 time steps with a resolution of 0.8 seconds have been acquired for the DCE-MRI part of the measurements. The spatial resolution of the dynamic data is $224 \times 224 \times 14$ with a voxel size of $1.78 \times 1.78 \times 2.5$ mm. A subset of 85 of the 450 time steps has been registered to make the analysis of TICs feasible.

Figure 1 shows two slices in the data set and TICs for the locations indicated in the slices. Apart from the second curve (obviously in air), all curves show the arrival of the contrast agent (CA) by a jump of the values. The curves for the two locations in the thickened bowel wall have very similar shape and mean value.

3 Methods

Our method is based on the fact, that regions important for diagnosis and monitoring are characterized by a strong increase in intensity after contrast agent administration during the measurements. Let $I(t)$ be the intensity at a selected location for a certain time t.

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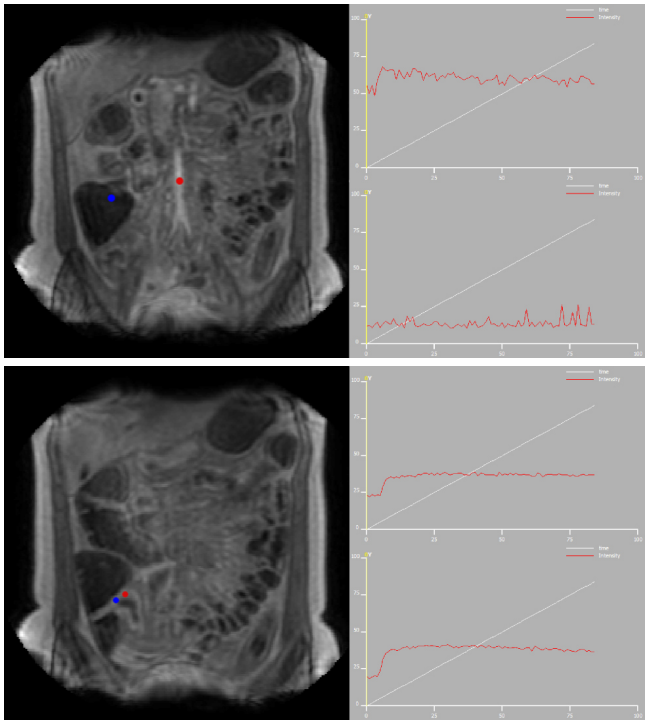


Figure 1: Time-intensity curves (right) for different locations in DCE-MRI data (left). The location for the upper graph is shown by a red dot in the slice next to it and the location for the lower graph is shown by a blue dot. The locations in the lower slice lie in the region of thickened bowel wall.

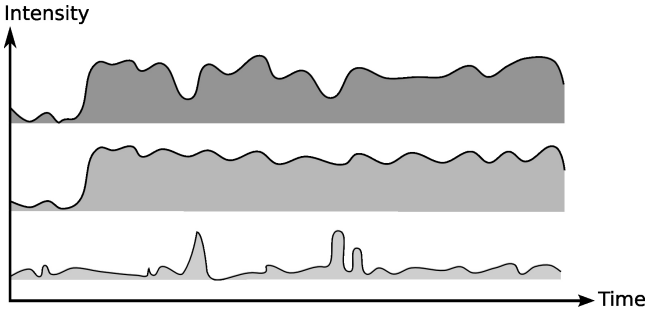


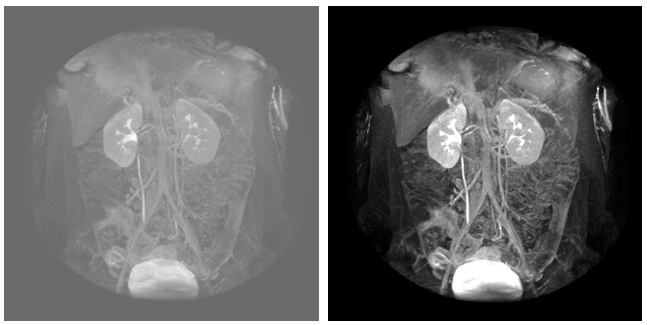
Figure 2: Examples for curve shapes. The *normalized integral* is indicated by the grey area under the curves. The lower curve showing mainly noise has a low integral value. The two upper curves both have a large integral. They show that the *normalized integral* depends only on the relative intensity (compared to their minimum) and not on the absolute intensity.

We compute A_c, the area below the TIC in the bounding box of the curve as

$$A_c = \int_{t_0}^{t_n} (I(t) - \min_{t \in [t_0, t_n]} (I(t))\, dt.$$

We use the term *normalized integral* for the area A_c. This computation is inspired by the *integral* which is used as a parameter of concentration-time curves (CTC) [2]. The main difference is that our method works on TICs instead of CTCs. Thus we are independent of the parameters needed to compute CTCs from TICs [1], some of which are dependent, among other things, on tissue type.

The *normalized integral* takes care of several typical features of the TICs. High frequency noise like the peaks in the lower curve of Figure 2 does not have a large effect on the integral and is thus filtered out. For A_c to make sense, it is important to note that, in the targeted data, the noise appears as peaks producing maxima and not minima. Additionally, the comparatively high intensity difference between the upper two curves, that could inhibit the emphasis of the interesting bowel wall parts, is compensated by normalizing the integral with the curve minimum.



(a) Difference pre and post CA administration.

(b) Difference pre and post CA administration. Selected data window.

(c) Difference of DCE-MRI steps pre and post CA administration.

(d) DCE-MRI step post CA administration.

Figure 3: MIP renderings of abdominal MRI (for details see image captions). The MIP uses the whole data range except where indicated. (c) and (d) are from the dynamic measurements that were acquired with a lower resolution and a different sequence than the MRI in (a) and (b). Please compare with new method in Figure 4.

The volume containing the *normalized integral* for each position represents the dynamic data in a way that emphasizes the wall thickening by assigning it high intensity values. To demonstrate the effective emphasis we render the volume using a simple maximum intensity projection (MIP).

4 Results

A rendering of the *normalized integral* volume is shown in Figure 4. The thickened wall (arrow) is very prominent in this image.

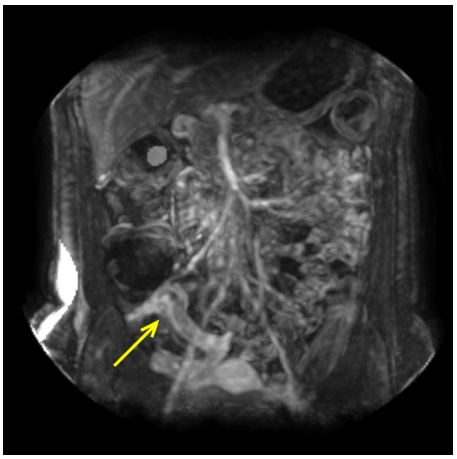


Figure 4: MIP of dataset containing the *normalized integral* for each position highlights the parts strongly enhanced during DCE-MRI measurement (thickened bowel wall, yellow arrow). Compared to four other standard volume rendering options with window leveling/processing in Figure 3, our normalized integral is the best.

To evaluate the effectiveness of the visualization we provide a couple of alternate renderings for comparison in Figure 3. The only rendering that can compete with the clarity of Figure 4 is the one where a data window has been manually selected (Figure 3(b)). In contrast to this rendering, however, our method needs no user interaction to adjust window/level setting to produce satisfying images.

These findings lead us to the conclusion that our method is superior to previously presented methods that also need no user interaction at all.

5 Summary

We presented a method that improves the volumetric visualization of abdominal MRI data in a way such that the physicians do not need to tweak any parameters or iterate through all slices in order to monitor the presence of at least one symptom of Crohn's disease (wall thickening with increased vascularization). In comparison to previous methods the symptomatic features are strongly emphasized without any user interaction thus allowing for an overall impression at a glance. The visualization is tailored to abdominal DCE-MRI measurements, which are expected to have an increasing impact on the diagnosis and monitoring of Crohn's disease.

For the future we plan to improve our method by taking into account the expected mean value of the TIC of affected tissue. This will allow us to make the interesting region even more prominent compared to the blood vessels (which have a much higher mean, see Figure 1). Furthermore, we are already working on improved interaction techniques.

Acknowledgements

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