Automatic Extraction of quasi-Synchronous Views from Rotational Angiography Sequence without ECG-Data

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3D centerline model reconstruction of coronary vessels from rotational coronary angiography sequences mostly involves ECG-data (electro-cardiogram) to detect synchronous views [1–3]. Of interest are the end-diastolic states, since the heart has the minimal motion in this state. Several problems arise with the usage of ECG data: Firstly, the assignment of heart states from the ECG-signal is not an easy task and can be unprecise. Secondly, examined patients can have coronary diseases such as arrhythmia and the ECG-data is therefore misleading. Thirdly, the next generation of C-arms does not offer the triggering with this signal. Finally there can be a difference between the electrical state and the observed mechanical state of the vessels [4]. So methods for automatic extraction of synchronous views directly from the images sequence and without ECG-data have to be developed.

Based on the idea of Blondel[4], the vertical motion of the heart can be extracted from the sequence by analyzing the curve of vertical motion. We preprocess the whole angiography sequence with an operator that enhances the vessels and reduces the background[5]. For each image the *horizontal integrals* are computed: For each row the sum over all columns is calculated. This integration marginalizes the horizontal motion and captures the vertical one. All horizontal integral-vectors (for each frame) are concatenated to get an image of vertical motion. The end-diastolic views are the maxima of the motion observed. See figure 1 for visualization of these steps. In order to extract them we extract the *curve of maxima* along each column and analyze it. This curve is an approximation of the curve of vertical motion. This contribution focuses on the extraction of maxima from the curve of maxima, as to say of the end-diastolic views. And on the detection of *irregularities* of the heart cycle observed to preserve just the regular maxima.

We propose a new method based on the following steps:

- Find the dominant period of the curve of maxima by performing a Fourier transform and picking up the frequency of highest amplitude. Due to the presence of irregularities and outliers, it is not sufficient to approximate the signal by a single sine curve and extract its maxima. We need a tool that enables us to find the maxima even in the presence of irregularities and outliers.
- Examine the local spectral characteristics of the signal by applying the short time Fourier transform (STFT). This transform explicitly indicates how the signal's frequency contents evolve in time. By a proper choice of the window function and its length, which is chosen to be the dominant period of the curve, we are able to produce a new curve of energy whose maxima coincide with the maxima of the original curve, but which is smooth and shows less instabilities wrt. outliers.
- The maxima of interest are extracted by looking for points whose first discrete derivative is close to zero and whose second derivative is negative.
- The detection of irregularities is performed by a spatial analysis of distances between the extrema of the new curve, taking into consideration again the length of the dominant period.

Figure 1, bottom, right visualizes the results of these steps.

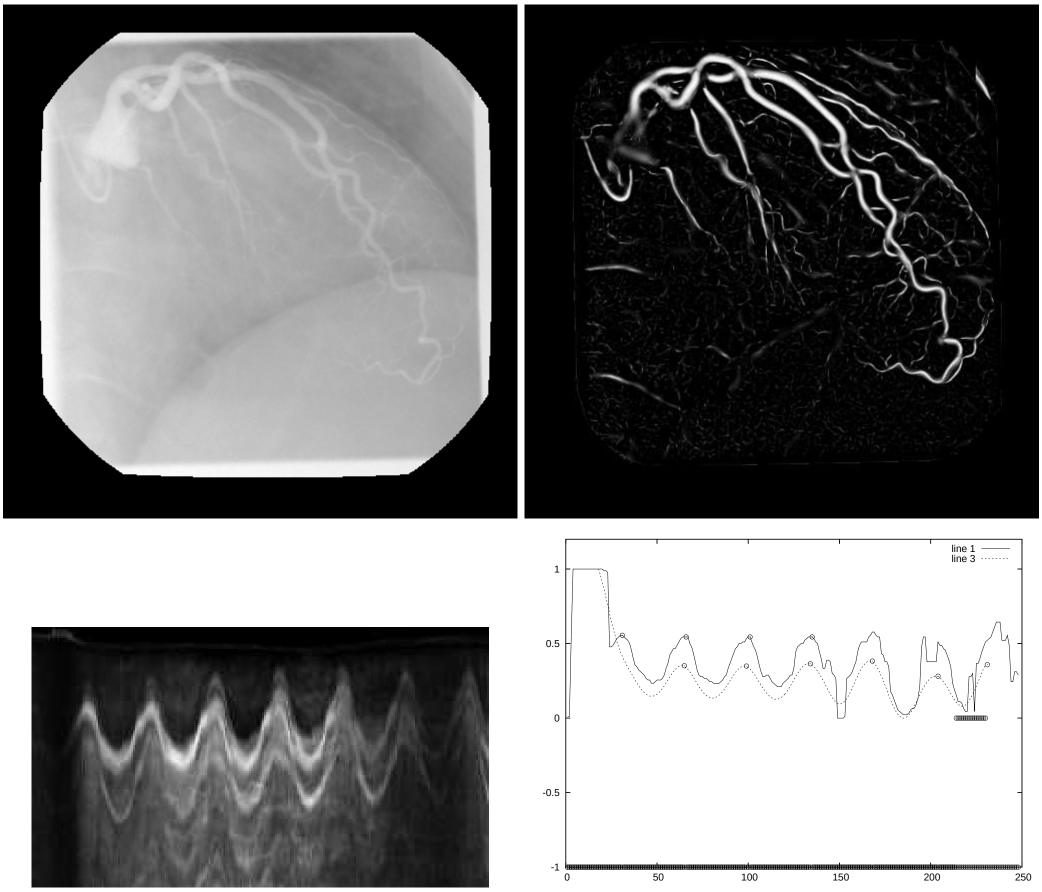

Fig. 1. From left to right and from top to bottom: original image. Preprocessed image. The image of horizontal integrals. The curve of vertical motion: curve of maxima (continuous line) and its approximation after spectral analysis (dashed line). The results of regular maxima extraction are showd on both curves.

In our experiments we use five sequences of real patients, captured during a rotational coronary angiography intervention, using a a Siemens AXIOM Artis system, each of them containing 248 views over an angular range of 200°. For each sequence we have also the ECG data. We report the ECG-states of the automatically extracted maxima in table 1. In this abstract just results on one sequence are reported.[1]

	results of the seq. of img 1				
Maxima on raw curve	29	63	99	132	
ECG-states	89.5	87.7	91.1	86.7	
Maxima on stft-curve	63	98	133	167	203
ECG-states	87.7	88.2	89.6	88.3	93.4

Table 1. Table summarizing the results of extraction of synchronous views of a sequence

The STFT-transform operates like an overall smoothing of the signal. Extracting the maxima using this curve, the method was able to detect extrema, which were corrupted by discontinuities in the original signal (the two last ones in the table 1). These maxima, however, do not coincide perfectly with the original extrema, so that an adjustment on the original signal may be necessary. The main problem with processing on the original signal is the existence of valleys of maxima. Future work will concentrate on the extraction of a starting curve, which is more robust to changes in gray values than the curve of maxima. The corresponding ECG-states of the extracted maxima deliver quasi-synchronous views within a small window. This is acceptable[6] since a 100% synchronization of acquisition and ECG-gating is almost impossible.

References

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[1] results on all sequences will be reported in the final paper