Cardiac valve position prediction in CINE-bSSFP images using SURF

H. J. Crooijmans[1], P. C. Cattin[2], O. M. Weber[1,3], and K. Scheffler[1]
[1]Division of Radiological Physics, Department of Medical Radiology, University of Basel Hospital, Basel, Switzerland, [2]Medical Image Analysis Center (MIAC), University of Basel, Basel, Switzerland, [3]Siemens Healthcare, Zürich, Switzerland

Introduction

Reliable evaluation of valvular morphology and function is important in a number of diagnostic questions. However, the analysis of cardiac valves with MR imaging is challenging: the cardiac valves are moving throughout the cardiac cycle. Earlier it was suggested to extract valvular motion from a tagged image and to use this information to actively follow the valve with the imaging plane (1). In order to eliminate the need for an extra scan and to simplify the workflow, we developed a method to track the cardiac valves throughout the cardiac cycle in CINE balanced steady state free precession (bSSFP) images. Tracking the valves with classical template matching methods is inherently difficult as they continuously change their shape or might not even be visible in some slices. In this research we therefore determine the valve positions indirectly through nearby trackable points or blob like regions. To track these points, we used the interest point detector and region descriptor SURF (2) which is computationally very attractive and allows future implementation on the MR system itself. SURF first locates interest points at distinctive locations in the image such as points or blobs. Then distinctive and robust features are extracted in the neighborhood of every interest point and put in a feature vector. As the same points in different images have a similar feature vector, corresponding points can be easily found by calculating the Euclidean distance between the feature vectors. Matlab (The Mathworks, Inc., USA) was used to process the SURF features and to find the valve positions in every phase of the cardiac cycle, which can then be fed back to the scanner and used to position the slices for the next sequence (e.g., a flow quantification sequence). This second acquisition will have the cardiac valve in plane in every phase (acquired image) of the cardiac cycle.

Methods

A 2D CINE-bSSFP acquisition in the four-chamber view orientation is performed with 40 phases per cardiac cycle on a 1.5 T Avanto whole body scanner (Siemens Healthcare, Germany). Sequence parameter settings are as follows: in-plane resolution, 1.77x1.77 mm^2; slice thickness, 6.0 mm; matrix size, 174x192; TR, 2.65 ms; TE, 1.12 ms; and a 71° flip angle. These CINE-bSSFP dicom images are analyzed using SURF, which determines image features suitable to be followed over different heart phases. The SURF features are read by a Matlab program in which the user has to perform the following steps: 1) pick a point in the right atrium; 2) select the feature out of the by the program suggested features which is best to use (based on step 1, see Figure 1a); 3) select the points of interest (POI), which are in this case the attachments of the valve of interest to the cardiac wall (Figure 1b). Now the Matlab program will find the positions of the POIs in all succeeding phases of the cardiac cycle. In case a found corresponding feature is further away than a preset value from the previous feature it is not used but interpolated. Interpolation is performed between two features that are found to be within the preset limit (one prior and one succeeding the failing feature). The program gives a warning when more than half of the phases are outside the preset limit and/or when more than five succeeding phases are found by interpolation.

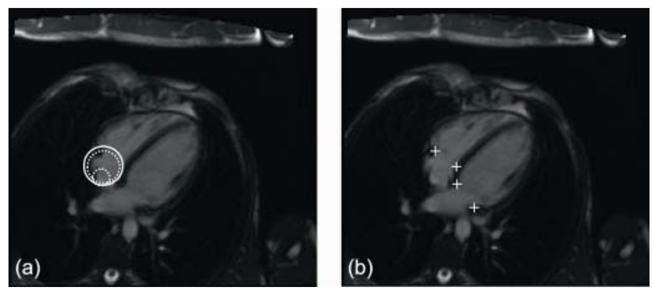

Figure 1 Indication of three features (continuous and dotted circles) in step 2, of which to select the best one (continuous line) (a). In the third step, the user indicates the POIs (white crosses) as indicated in (b).

Slice position and orientation are then calculated based on two POIs that indicate the position of one valve, together with the normal vector of the CINE image: together they describe the new image plane. It is thus assumed that the CINE acquisition is perpendicular to the valve. The slice definitions for all cardiac phases are passed on to the MR imager for subsequent slice-following imaging, i.e. with optimal slice position and orientation for every phase of the cardiac cycle.

Results

An example for found POIs over the cardiac cycle is shown for six out of 40 cardiac phases in Figure 2. Not for all cardiac phases of the presented case a feature was found to be within the limits. In those cases, the POIs positions were interpolated. An example is shown in Figure 2c.

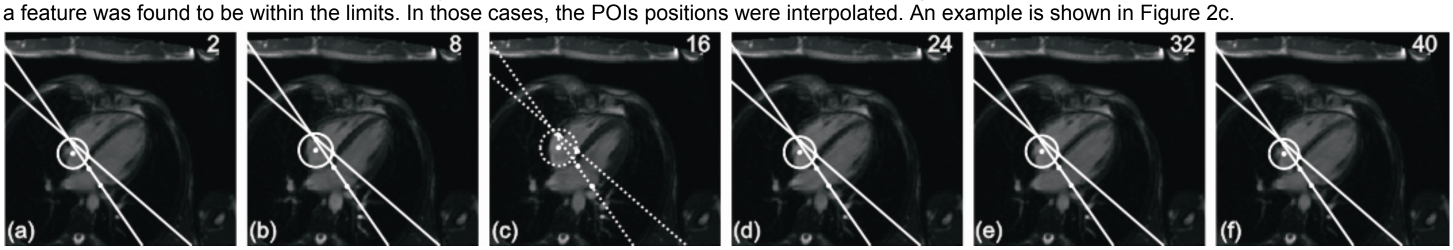

Figure 2 The found valve positions in 6 cardiac phases (cardiac phase nr is indicated in the top right corner) as well as the found feature. In cardiac phase 16 (c), no corresponding feature within the limits was found, therefore interpolation was used (indicated by dotted lines).

Discussion/Conclusion

This study demonstrates that SURF can be used to find the POIs defining a cardiac valve throughout all cardiac phases in CINE-bSSFP images after definition of these POIs in the first phase. In some cases, the Matlab program was not able to find a SURF image features within the preset limits; instead, the POIs were defined using linear interpolation. Although the user could have manually labeled the position of the valves in every frame, user intervention should be kept at a minimum, as prolonged labeling bears the danger that the heart slightly drifted away from its previous position rendering the estimated imaging planes inaccurate.

The presented method has given promising results supporting further research and development such as improvement of the interface; user feedback to change the results if desired; and the use of the found image positions and orientations in a slice-following sequence.

References

(1) Kozerke et al. Magn Reson Med 1999;42:970-978. (2) Bay et al. CVIU 2008;110(3):346-359.