FOVEA - Direct comparison of compression artifacts in cardangiography

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The FOVEA system is designed to visualize the morphology of diagnostically significant details in coronary angiograms by a motion compensated movie display. The visual feature extraction of small moving structures with low contrast is the most difficult task in cardiac imagery. At present, there is no method available to proof a lossy digital cine system as to be sufficient for all the cardiologist's needs. The commonly used error measures or quality factors can´t guarantee limits for the degradation of the moving regions of highest medical interest. Therefore, a subjective evaluation of the clinical quality of digital cineloops is required. We use the FOVEA system here as a visualization testbed for the dynamical worst-case comparison of angiographic sequences under different types of image degradations. A simultaneous display of the original and the lossy compressed sequence allows to inspect the influence of the compression artifacts on clinical decisions.

1. INTRODUCTION

One of the major objectives in angiocardiography is the visualization of anatomical details of a vessel segment of interest. Safety and success of diagnostic and interventional angiography depend on the proper visualization of all potentially relevant medical details. Cinefilm is still the gold standard for image sequence archiving in cardiac angiography because of its perfect visual resolution, longterm stability and global exchange compatibility. However, digital successors compete for standardization.

1.1 Digital angiography

Modern cathlab imaging equipment offers great online visualization improvements like looped playback, realtime image enhancement or synchronized pre/post compare. The quick and easy shortterm access to the actually acquired image sequences facilitates a direct report immediately after the investigation. However, reporting after film development can offer additional information in some cases: the

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visual detection of diagnostically significant small structures (e.g. vessel dissections, thrombi or stents) potentially needs all resolution available. *Every replacement of the film consequently has to guarantee, that all medically relevant image details are fully preserved.* Image quality is consequently defined here as the usability of the image sequences in clinical practice.

1.2 Quality control

At present, there is no method available to quote a lossy system as to be sufficient for all cases. Therefore cardiologists demand for a digital image archive with film-like resolution and non-lossy image compression. Unfortunately today's digital archiving technology can't handle the giant amounts of data resulting from this demand. Therefore strict data reduction is required. A good compromise between maximum image quality and minimum data size seems to be difficult to find. At present, no mathematical quality parameter is available reflecting the visual perception performance on medically significant image details. The commonly used peak-signal-to-noise-ratio calculated over the whole frame is not capable to describe the reproduction quality of the medically relevant objects. The display of small moving objects with low contrast like dissections, thrombi or stents remains the most critical task during catheter interventions.
The scope of this work is focused on the visualization of those objects for a subjective evaluation of movie compression algorithms in cardiology.

2. APPROACH

The FOVEA system enhances the visual detectability of small low-contrast details. It allows a magnified simultaneous display of two running cine-loops without a global movement of the object of interest. If experienced observers can't detect any medically relevant differences in such a pair of loops displaying a worst-case-object, the visual feature extraction performance of both loops can be quoted as equal.
The motion compensated display is proved to enhance the detectability of those objects [1][2]. Therefore, the corresponding full frame loops should equally perform too on the commonly used (filtered interpolation) displays, supposed to the observer has chosen the most critical parts of the frame.

3. METHOD

FOVEA stands for "Focusing object velocity equalization of angiograms". The main principle of the method is to fix the vessel segment of interest on the screen during the run of the loop. This helps the human psychovisual system to detect moving lesions in structured noise. The method combines the advantages of both, the still and the movie display without their disadvantages.

3.1 Static vs. movie display

A still frame of the coronary tree is not sufficient, because the assessment of the dynamical morphology of the vessel is diagnostically unrenouncable. In addition, the detectability of low contrast details is limited by the heavy quantum noise that is not decreasable because of radiation safety. The advantage of the still display is the ability of the human observer to focus the object of interest to the retinal area of highest resolution (fovea centralis) even under magnification.

The movie display allows the observer to gain an imagination of the dynamical morphology of the objects of interest. If the frame rate is high enough, the variants of the same shape can be distinguished from noise, because the (uncorrelated) noise is averaged by the observer's psychovisual system. Unfortunately this human postprocessing is inhibited, if the object of interest is displayed at different regions of the retina. This disadvantage is sharpened, if the object is magnified. The eye follows the object discontinuously (saccade movement) disturbing the shape identification capability. This is why all cardiac cinefilm-projectors have several adjustable frame rates.

3.2 Motion compensated display

A zoomed running display of a critical vessel segment at a fixed screen position enables a better detection of weakly bound small structures in the vessel. The frame rate can be increased for better noise suppression even under magnification of the shape. The eyes of the observer can remain focused on the object. The trajectory of the object is derived from a series of mouse clicks to gain the positions of the object related subframes from both the original and the lossy sequence. A synchronized biplane display is generated by interpolated rescaling to the display size. The psychovisual image processing capabilities of the observer are supported at best, if the interesting object is displayed magnified, with minimum displacement at the highest frame rate available.

3.3 Properties of FOVEA

The generation of a FOVEA sequence from the cinefilm allows a zoomed running display of the points of highest medical interest at full film resolution. This technique offers the storage of film-like resolved angiographic information on low resolution devices. Therefore it is possible to compare cine-loops with higher resolution than the used display system. This is an important step to direct visual comparison of high resolution grayscale movies.

The motion tracking generates an inversion of motion: The prior static background showing tissue and bones begins to move. This effect enables the observer to concentrate on the more relevant structures of the movie.

In addition, the difference image sequence is generated to visualize the texture of the compression artifacts by color-encoding. For an optimum image reproduction, the errors should look like uncorrelated noise in the areas of medical interest. If vessel boundaries are seen in the error movie, significant information is lost. This testbed should deliver a better visualization of compression artifacts than the usual comparison of two digital fullscale still frames. This technique offers the ability to test image degradation under dynamical worst-case conditions.

4. EXPERIMENTS

In a pilot study, we tested pairs of image sequences of the same patient under identical geometric conditions, one from the SIEMENS prototype of a digital solid state detector with a 1000x1000 matrix, the other from a conventional image intensifier system. Another pair comes from a SIEMENS HICOR system and the associated cine-film. The investigator marked the loops for the position of stents, dissections or thrombi. The loops were degraded by several destructive processes like averaging to 512x512 matrix, storing to S-VHS tape, compressing by motion JPEG, MPEG and Fisher´s fractal codec [3]. This pool of loops was processed by FOVEA, paired randomly and displayed via the HICOR system and alternatively by a videoprojector. The feedback of clinical observers is associated with calculated peak-signal-to-noise-ratios. Those ratios were compared to the signal-to-noise ratios of the extracted regions only. The difference is used as an indicator for the error distribution related to the medical relevance of the error.

5. DISCUSSION

The FOVEA display allows to distinguish several compression algorithms much better than the commonly used calculation of peak-signal-to-noise-ratios. The ratios calculated on the displayed regions only, show different deviations from the full frame ratio depending on the compression method used. Methods working with static block-partitioning like JPEG or MPEG 1 tend to generate visible artifacts even at the regions of high observer attention, while the adaptive quadtree partition of the fractal codec reproduces regions with fine structures nearly as good as the full frame. The S-VHS storage is generally unacceptable for coronary angiograms. We found only one example, where the cinefilm performed worse than the digital 512^2 original (because of insufficient film development).
Every potential successor of the cinefilm has to be compared by FOVEA to the digital original *and* cinefilm itself. We are planning a multicenter study to increase the amount of testsequences, compression techniques and clinical observers.

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