Quality Preserved Image Data Coding in Angiography Migration from Cinefilm

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Abstract

One of the major objectives in angiocardiography is the visualization of anatomical details of a vessel segment of interest. The excellent resolution of the cinefilm can't be reproduced by today's digital systems. A universal compromise between image quality and strong data reduction is difficult to find. In this paper we propose the concept of image content descriptions as related parameters to be stored with(in) the image. The image frame is divided into regions of different medical significance allowing different degrees of data reduction and quality enhancement. This concept is illustrated by several examples: the 3D-reconstruction avoids unnecessary data, the motion compensated loop preserves the film resolution in critical regions, and the predictor-corrector postprocessor, tunes an arbitrary lossy compressor to become partially nonlossy in the most important regions of the image.

1. Introduction

Safety and success of diagnostic and interventional angiography depend on the proper visualization of all potentially relevant medical details. Image quality can be described as the usability of the image sequences for all possible clinical evaluation needs. Years of image intensifier development resulted in a remarkable increase of the overall resolution. Cinefilm is still the gold standard for image sequence archiving in angiography because of its perfect visual resolution, longterm stability and global exchange compatibility. But a migration from cinefilm to digital archives is necessary because of the well-known handling problems of the chemical development. A digital archive would eliminate the media diversity and enable digital integration of different image sources (e.g. US, PET, MR) and image related parameters (e.g. ECG, QCA, 3D).

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 visual detection of diagnostically significant small structures (e.g. vessel dissections, thrombotic lesions) potentially needs all resolution available. Every replacement of the film consequently has to guarantee, that all *medically relevant* image details are fully preserved. Therefore most cardiologists demand for an 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 [1]. Therefore strict data reduction is required. A good compromise between maximum image quality and minimum data size seems to be difficult to find.

2. Approach

Optimized data reduction should deliver the minimum data set required for an optimum visualization of all interesting details. Our approach is to increase the amount of image related parameters by image content descriptions. The image frame is divided into regions of different medical interest. This *significance segmentation* enables the use of different coding schemes adapted to the different quality requirements of the cardiologist.

A *Point of Medical Interest* (PMI) is defined as the location of a critical part of the X-rayed object (usually a vessel segment). The image coordinates of such a PMI depend on the projection angle and the phase of the cardiac cycle. Another description element is the *Region of Potential Medical Interest* (RPMI). It is used to qualify the member pixels to be relevant for the clinical evaluation. *Image quality* is consequently defined here as the usability of the display for the clinical evaluation of the PMIs and their environments.

The additional storage of such image content descriptions enables data reduction and quality

enhancement methods adapted to the attention the cardiologist pays to. Most significant information is preserved, other image parts can be stored with loss of information. Non-significant regions can be used to store the image related parameters within the image (intra frame coding) [2].
In this paper we present three examples how data reduction can be improved by using image content descriptions.

3.1 3D-reconstruction of the Coronary Artery Tree

We developed a procedure to reconstruct the 3D-structure of the coronary arteries from the primary diagnostic session. This is done by the alignmet of a set of connected 3D-Bézier curves to both projections of the vessels [3-5]. The course is entered interactively by the definition of anchor points an their tangents to the vessel. During the generation of the 3D-representation of the coronary tree points of high medical interest (PMI) can be defined.
A computer simulation allows an interactive search for a nearly orthogonal view on the PMI vessel segment without overlap by other segments within the machine collision boundaries. Using the computer mouse in a similar way as the gantry joystick the doctor can adapt the view to the individual morphology of that coronary tree. The procedure is illustrated in figure 1.

The found projection angles can be used to start future investigations under optimum visual preconditions avoiding data generation (and radiation exposure) from overview or projection search phases. This interactive postprocessing is able to quantify the quality of the projection with respect to the given PMI vessel segment.
The storage of a PMI and its associated viewing angle as an attribute of a tree segment is one example for a more general adressing concept: the use of the 3D-tree model as an adressing scheme for localized investigation results. The diameter analysis of a stenose - for example - located in the middle of the 12. Bézier curve can be simply stored as "diameter at tree position 11.5". Keeping all image related parameter together in such a consistent way improves image quality in terms of the prior definition.

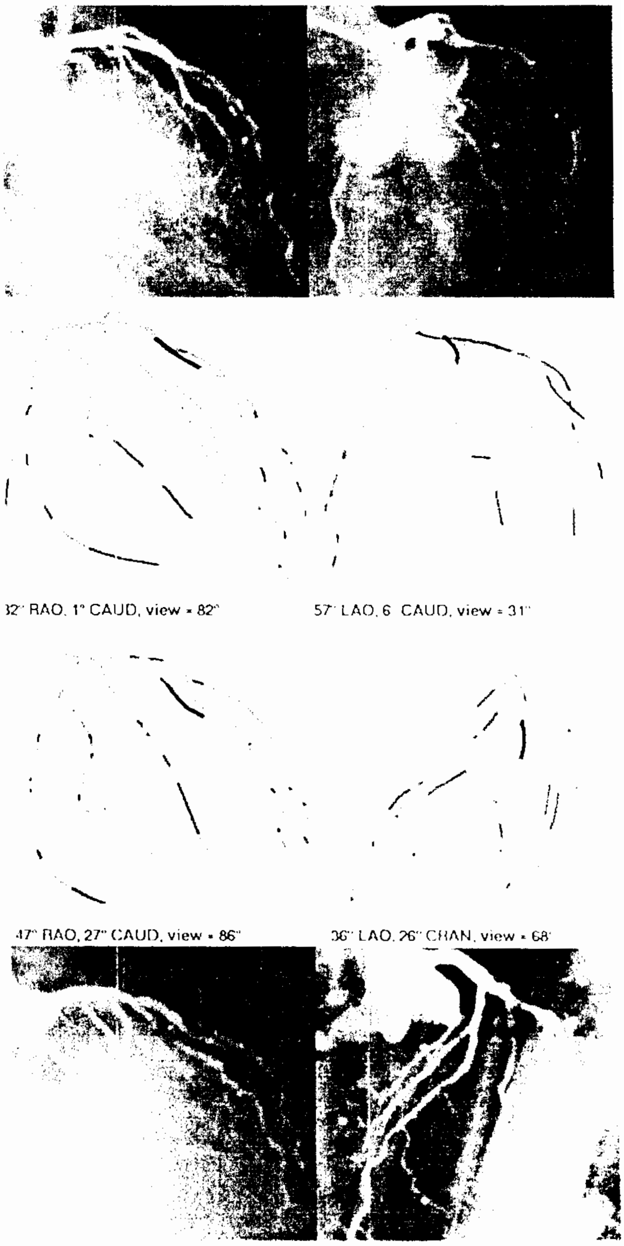

Figure 1:
Biplane angiograms and simulated projections of the reconstructed tree. The upper half was acquired at standard views, the lower half shows the optimized views. All nearly orthogonal segments are shown in dark gray, the PMI segment is marked in black. The simulation displays the actual projection angles and the viewing angle. An orthogonal view on the PMI segment would result in "view=90°".

3.2 Motion Compensated Loop

Small low contrast structures can be distinguished from noise in the running display only, because the psychovisual system averages the percepted noise of several frames. The noise is dominated by the the statistical fluctuations of the X-rays (quantum noise), which is reverse proportional to the square of the radiation dose [6]. Since the dose can't be arbitrarily increased, an inspection of still images is not sufficient. On the other hand a still image enables the observers eyes to focus on a PMI. The movement of the PMI in the running display inhibits this focussing because the eye follows the PMI at higher frame rates discontinuously (saccade movement). Furthermore a zooming of small structures is limited: the growing amplitude of the PMI's movement enhances the eye tracking problem.
The visibility of small critical structures can be considerably improved, if the visualization combines the advantages of both the still and the movie display. The idea of the motion compensated loop is to fix the PMI at the screen [7]. If the position of a PMI is corrected to constant screen coordinates for all frames, the observer can easily focus the PMI on the fovea centralis and diminish the subjectively percepted noise by displaying the running loop.
This method generates an inversion of movement by exchanging the amplitudes of the PMI and the background. The generated "tranquilized loop" supports the "image processing capabilities" of the psychovisual system for a better visualization of the morphological dynamics of medically significant image details.
The generation of a motion compensated loop from the cinefilm allows a zoomed running display of the PMI at full film resolution. This technique offers the storage of film-like resolved angiographic information on low resolution devices. Although this is possible for cinefilm users only, the method offers medically relevant information in a new compact form sufficient for digital or videotape distribution.
The possibility to copy the relevant information to a video tape eliminates the distribution problem of the archived cinefilm, which is typically requested simultaneously from several places in the hospital.
The same method can be used to inspect the information degradation of digital archive solutions. A zoomed motion compensated loop derived from a digital image sequence allows a direct dynamical comparison of different resolutions or lossy compression methods with the higher resolving cinefilm (Fig. 2). This technique offers the ability to test image degradation under dynamical worst case conditions. This testbed should deliver a better visualization of compression artefacts than the commonly used comparison of two digital fullscale still frames.

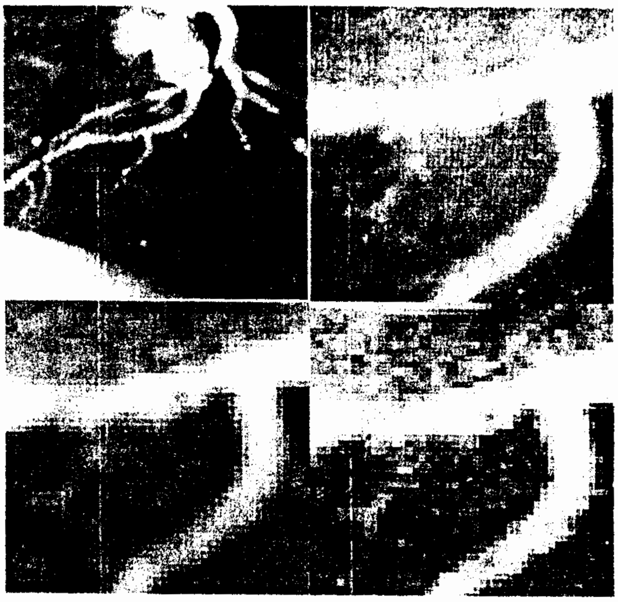

Figure 2:
Angiogram with a small, but highly signficant thrombotic lesion and more distal a dissection.
Upper left shows the digitized full frame.
Three samples show the same PMI at different stages of image degradation.

Upper right:	zoomed cinefilm.
Lower left :	zoomed digital acquisition (512^2).
Lower right:	zoomed, lossy compressed digital image (JPEG).

3.3 Partially nonlossy image compression

In extent to the concept of interactive PMI selection regions of potential medical interest (RPMI) are defined to preserve all information after arbitrary lossy compression by the additional storage of all compression errors on RPMIs only (Fig.3). After decompression, the display of an RPMI (e.g. the course of a vessel) is guaranteed to be free of compression artefacts. The overall compression ratio of such a "Predictor-Corrector" scheme depends on the area of the RPMI(s), the used quality factor of the lossy compressor and the goodness of the approximation especially on the RPMI. An increased degradation of uninteresting parts of the image is tolerable. However, major artefacts in the image background can irritate the observer and should be kept under the perception limit. Special attention should be payed to the RPMI borders to minimize borderline artefacts (known from Motion-JPEG). Modern compression techniques like Fractals or Wavelets provide to produce less irritation compared to the standard compression method Motion-JPEG.

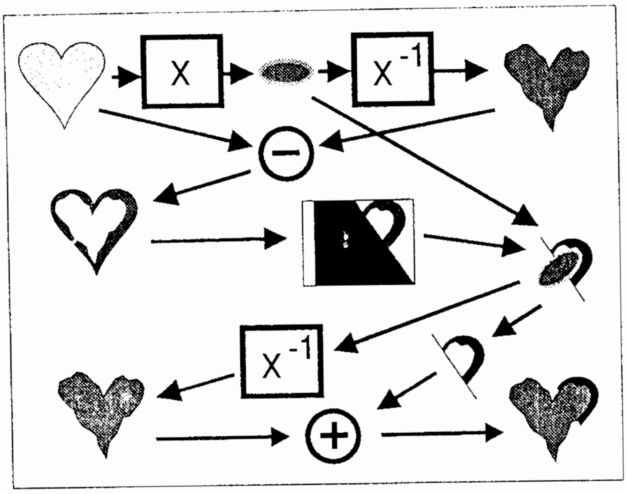

Figure 3:
Predictor-Corrector postprocessing after arbitrary lossy compression X and associated decompression X^{-1}.
In extent to the compression X (predictor) the compression error is calculated. The RPMI-mask cuts the interesting part of the error image (Corrector) and stores it with the compres-sed image.
In extend to the decompression X^{-1} the stored corrector is added to the decompressed image providing absence of compression artefacts on the RPMI.

4. Discussion

The proposed interactive image postprocessing during the report phase can improve all types of possible data reduction: the 3D-reconstruction of the coronary tree with subsequent simulation of arbitrary 2D-views avoids unnecessary data generation from repeated overview or projection search acquisitions. The procedure takes app. 30 min to complete the reconstruction.
At present, it is not possible to reconstruct the tree automatically. It is also difficult to train the computer for proposing optimum views. We found, that very often an orthogonal view without gantry collisions is possible for one plane only. The total amount of avoided radiation, dye and data is presently under investigation.
For both the 3D-reconstruction and the motion compensated loop an automatic description generation is needed to introduce the methods in clinical routine.
The generation of the RPMI depends on the observers opinion. A conservative choice is the use of the envelope around all vessels. Higher reduction rates are possible by using the vessel courses.
The concept of image content description needs a standardized way to archive image related parameters. Data integration by Intra Frame Coding offers independence from the used archiving systems, provided that standard raw image format and a non-lossy compression technique is used in the archive.
Quality preservation in critical regions combined with effective data reduction is an important step towards film replacement.

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