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SHORT COMMUNICATION

Interpolation Technique in Computed Tomography Image Visualisation

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ABSTRACT

An interpolation technique has been developed for generation of enlarged dataset from a limited one-dimesional acquired dataset for improving the image quality in quick-scan tomography. The effectiveness of the technique has been tested using data acquired from the first-generation computed tomography (CT) system. The CT images generated using this technique have been compared with the CT images generated from the acquired dataset for the same number of projections. The image quality has been improved on account of (i) enhancement of features, (ii) reduction in reconstruction artifacts, and (iii) magnification of the image without pixelisation.

Keywords: Interpolation technique, quick-scan tomography, first-generation CT system, CT images, tomographic image, computed tomography, imaging techniques, image processing, image visualisation

1. INTRODUCTION

Computed tomography (CT) is an advanced imaging technique which provides complete object visualisation in terms of cross-sectional details, thereby making it possible to resolve all internal details in their true spatial and angular perspectives. The tomographic image can be reconstructed from the acquired one-dimensional projections, using back projection techniques. It has been observed that the quality of reconstructed image is a function of the quality and quantity of data fed for reconstruction[1]. The mathematical theory governing reconstruction of an image from its projections requires an infinite set of projection data for obtainting an ideal CT image[2]. However, this is not feasible practically, as data acquisition process is a physical and time-consuming task, eg, with a typical first-generation CT data acquisition system, time required for data acquisition for a sample can go up to 20 h, if a set of 100 projections with 400 rays per projection is taken. Therefore, it is essential to adopt suitable techniques to achieve acceptable image quality even from a limited dataset.

In the present study, interpolation technique based on convolution of sinogram with interpolation operator is used to generate additional data set. The reconstructed image, using the interpolated data, shows enhanced image visualisation in CT images through reduction in reconstruction artifact and non-uniformity. This technique could bring out the features which, otherwise, were not visible even with a limited data set, thus resulting in considerable saving in data acquisition time.

2. METHOD

2.1 Theory & Approach

In the simplest form of CT scanning, i.e., the first-generation arrangement, a finely collimated beam of radiation passes through the object in the

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desired slice plane and the attenuation is measured. This attenuation is also referred to as a ray-sum. A set of ray-sums, i.e., projection, is obtained by stepping the beam across the object at a small interval. The process is then repeated and a set of projections is acquired as the beam is passed through the object at different angles. In a CT scan, if the ray-sums could be acquired with an infinitely narrow ray of radiation and the angular increment was vanishingly small, the result would be a continuous set of projections, each comprising a continuous set of ray-sums. These projections, when displayed as a 2-D function, are termed as the radon transform[3] $g\ (s,\theta)$ of the function $f\ (x,\ y)$.

The function $g(s,\theta)$ is the one-dimensional projection of $f\ (x,\ y)$ at an angle θ. The radon transform maps the spatial domain $(x,\ y)$ to the domain (s,θ). Each point in the (s,θ) space corresponds to a line in the spatial domain $(x,\ y)$.

If (r,ϕ) are the polar coordinates of $(x,\ y)$, that is

$$x = r\ \cos\phi,\quad y = r\ \sin\phi$$

then

$$s = r\ \cos(\theta - \phi)$$

For a fixed point (r,ϕ), this equation gives the locus of all the points in (s,θ), which is sinusoid and leads to a sinogram[4].

In the present approach, the set of one-dimensional parallel projections acquired by the first-generation CT system was first converted into a sinogram. The sinogram was enlarged and converted into a dataset for reconstruction. The enlargement process is based on the convolution of sinogram with an interpolation operator. In convolution, a kernel of numbers is multiplied by each pixel and its neighbours in a small region, the results are summed up and are placed in the original pixel location. This is applied to all the pixels in the image representing the sinogram. In all cases, the original pixel values are used in multiplication and addition and the new derived values are used to produce a modified image[5].

Various interpolation operators were studied and implemented. The interpolation operators, which have been found the most suitable for this application, are cubic B-spline interpolation operator and an extension of cubic B-spline interpolation operator. These operators can easily be derived by successive convolution of a square operator with itself. A typical square operator can be represented[6] as

$$\begin{matrix} 1 & 1 \\ 1 & 1 \end{matrix}$$

It has been observed that the choice of interpolation operator vary from sample to sample, depending upon the results.

2.2 Software Development

Since the quality of the reconstructed CT image is dependent on the choice of interpolation operator and the type of enlargement (enlargement of only the projections, enlargement of only the rays per projection, or enlargement of both), a software has been developed so as to fulfil this task and find the appropriate choice. The software has been developed using C language (ANSI standard) in LINUX environment and on a pentium machine. This GUI-based, user-friendly software accepts the acquired data set of one-dimensional parallel projections as input along with the various options for enlargement and interpolation operators. The output of the software is the enlarged dataset. The software also displays the original sinogram as well as the enlarged sinogram. The image is reconstructed with this enlarged dataset with the help of another software, namely, parallel beam reconstruction software, using filter back projection algorithm with RamLak filter[7].

3. DATA ACQUISITION

To test the correctness of the approach adopted, the data acquisition has been carried out for various samples using a CT data acquisition system, designed and developed at the Defence Laboratory, Jodhpur (Fig. 1). It is the first-generation CT system, using parallel beam geometry. It comprises a radioisotopic

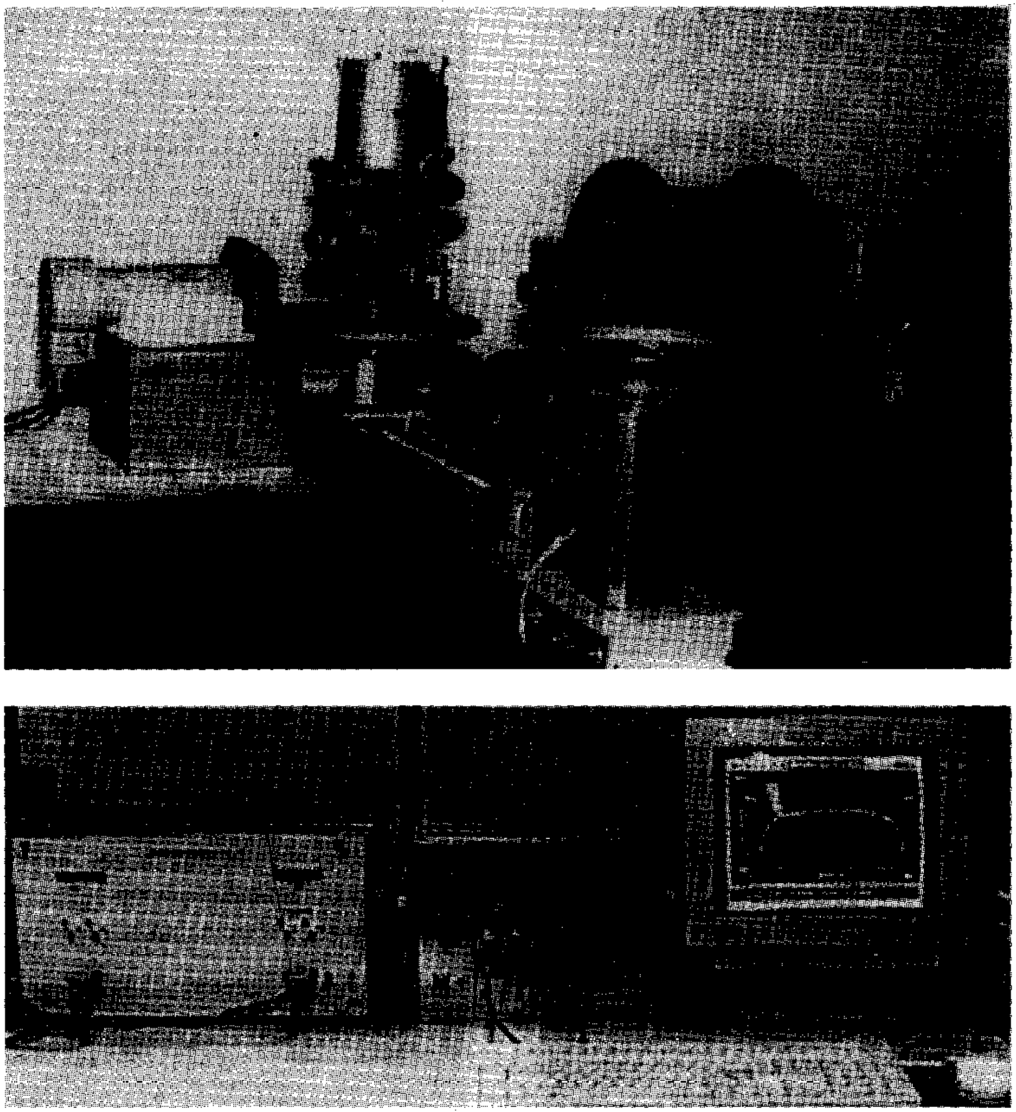

Figure 1. Computed tomography data acquisition system developed at DL, Jodhpur

source, a detector (collimator at source and detector ends) and a computer-controlled mechanical manipulator having the facility for selection of incremental steps in translational and rotational movements as per the requirement of the object being scanned.

The data has been acquired for three representative samples. Sample 1 is a resin disc of 150 mm diameter having five holes each of 1.1 mm diameter. Sample 2 is a brass rod of 2.5 mm diameter having three holes each of 1.1 mm diameter, one v notch of 3 mm length and one rectangular groove (2 mm × 2 mm). Sample 3 is a rectangular steel piece(22 mm × 25 mm) with many holes and a notch.

4. RESULTS & DISCUSSIONS

This interpolation technique for quick-scan tomography has been tested for samples of different sizes and shapes. Its capabilities have been demonstrated on the aspects as (i) feature enhancement, (ii) reduction of reconstruction artifacts, and (iii) image magnification without pixelisation.

4.1 Feature Enhancement

Figures 2 and 3 show the sinograms for the acquired dataset and for the enlarged dataset (sample 1), respectively. The acquired dataset is with 100 projections and 412 rays per projection. The enlarged data comes out to be 200 projections and 412 rays

Figure 2. Sinogram with acquired data for sample 1

per projection. Both the sinograms seem to be similar, thereby suggesting the correctness of the approach adopted.

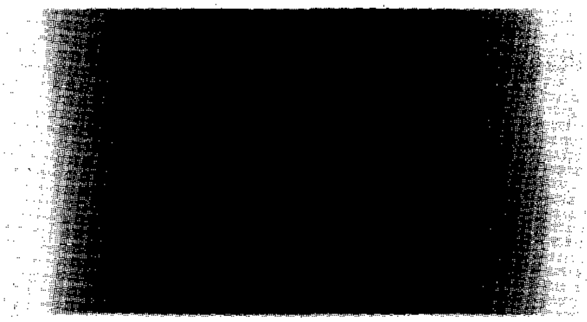

Figure 3. Sinogram with enlarged data for sample 1

Figures 4 and 5 show the reconstructed CT images from the acquired dataset and that from the enlarged dataset using this technique, respectively. The enhancements in features are clearly seen in the CT image (Fig. 5). The defects, which could not have been detected in the image (Fig. 4) are

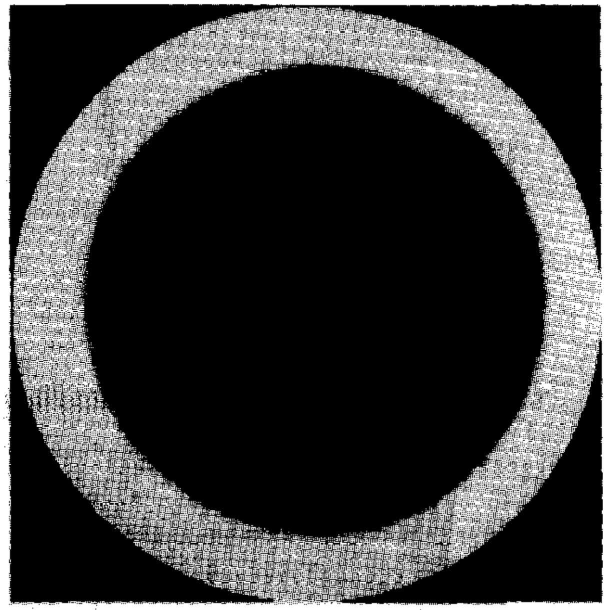

Figure 5. Reconstructed image with enlarged data for sample 1 (200 projections).

clearly located in the image (Fig. 5). For the confirmation of the defects, another set of data with 300 projections and 412 rays per projection was acquired and the image was reconstructed as shown in Fig. (6). In this image, defects are visible. The utility of the technique for enhancing the features in CT image is thus demonstrated. As typical data

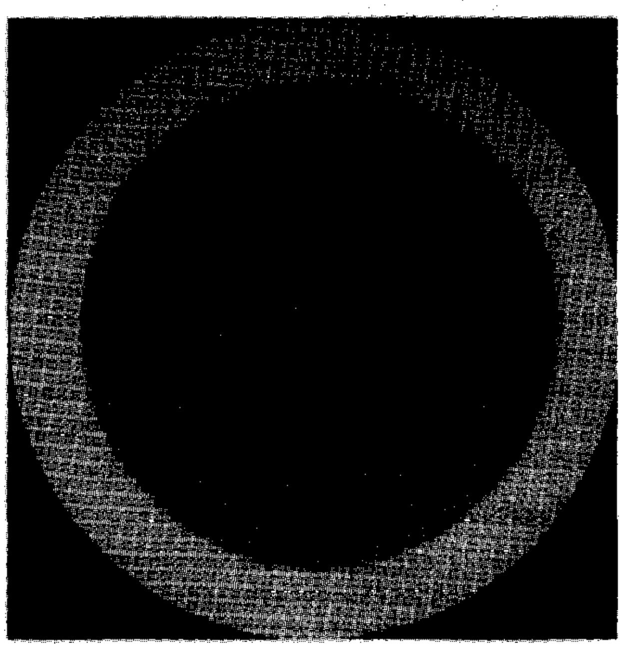

Figure 4. Reconstructed image with acquired data for sample1 (100 projections).

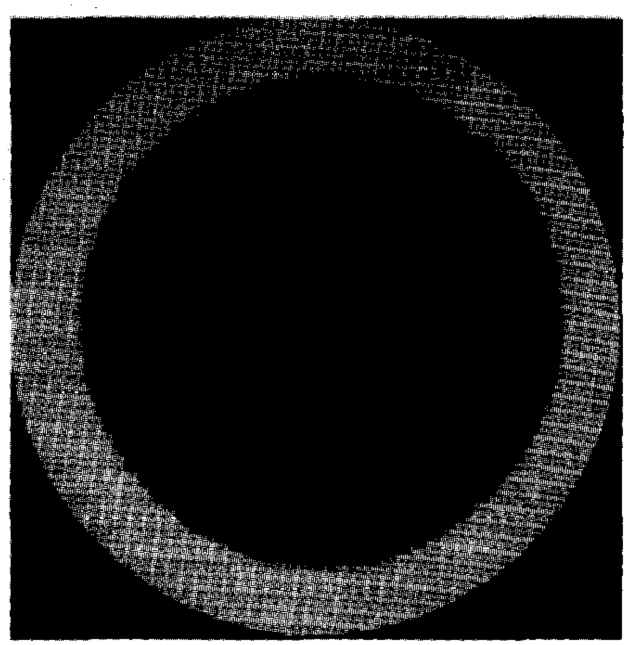

Figure 6. Reconstructed image with acquired data for sample 1 (300 projections).

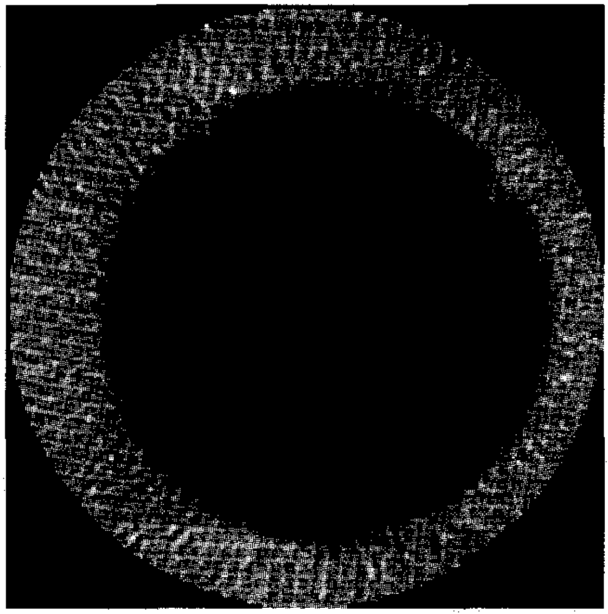

Figure 7. Reconstructed image with acquired data for sample 2 (100 projections).

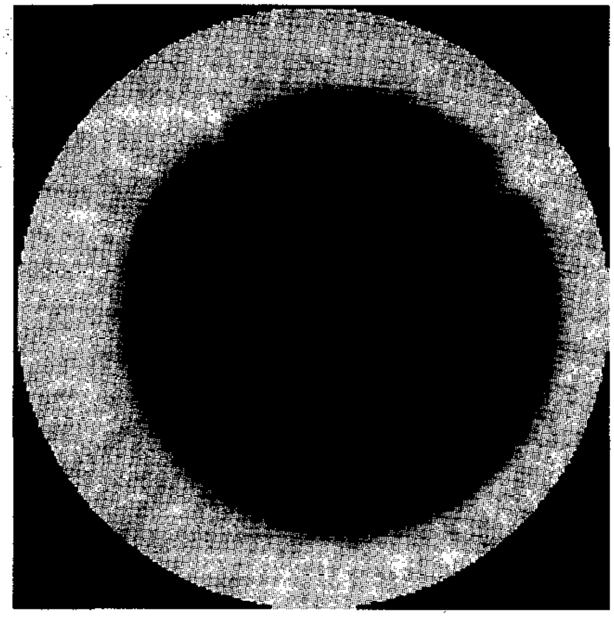

Figure 8. Reconstructed image with enlarged data for sample 2 (200 projections).

acquisition time for 100 projections was 16 h and that of 300 projections was 64 h, a tremendous time reduction (48 h) has been achieved in this case.

4.2 Reduction of Reconstruction Artifacts

The images reconstructed for an object from the acquired dataset (Fig. 7) and the enlarged dataset (Fig. 8) have been shown for sample 2. The image (Fig. 8) shows a significant reduction in reconstruction artifacts due to improved N rays/M projections ratio from 117/100 to 117/200 using present interpolation technique. The usefulness of this aspect can be realised by the fact that most of the quantitative CT applications demand that CT images should be free from artifacts[8]. Moreover, it is also giving a benefit of reduction in data acquisition time by a factor of approximately 2 in this case, which is quite significant.

4.3 Image Magnification without Pixelisation

Figure 9 shows the image reconstructed for an object from the acquired dataset and Fig.10 shows the image of an enlarged dataset for sample 3. Figure 9 is having an image 128 × 128, which has been enlarged up to 512 × 512 (Fig. 10) i.e., four times using this technique. It can be clearly observed that even if image has been magnified four times, no pixelisation is seen, which otherwise is a major problem in obtaining magnified images through other approaches (as in Fig. 11). The image can also be magnified eight times (i.e., to a size of 1024 × 1024) without pixelisation effect. This feature implies the usefulness of this technique in image magnification.

Thus, it is seen that though the same interpolation technique can be applied on the reconstructed image directly instead of sinogram, the results are better in the case of enlargement through sinogram.

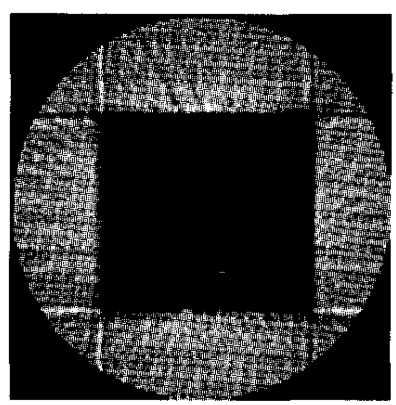

Figure 9. Original image for sample 3

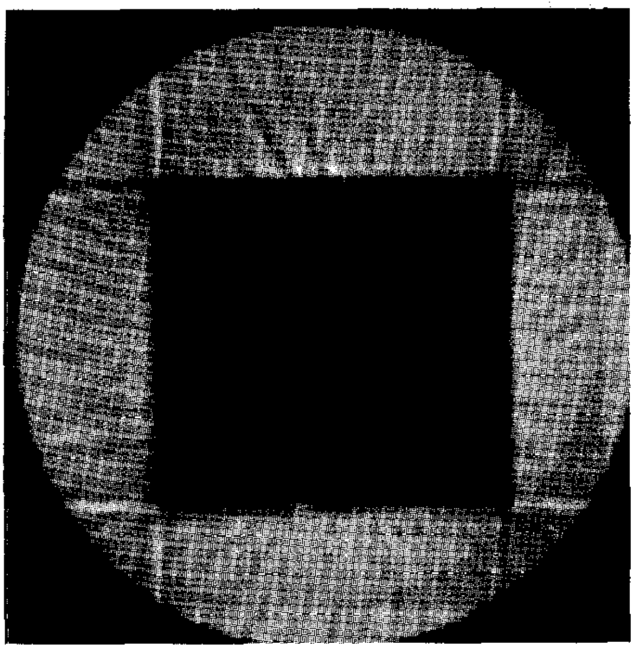

Figure 10. Enlarged image with enlarged data for sample 3

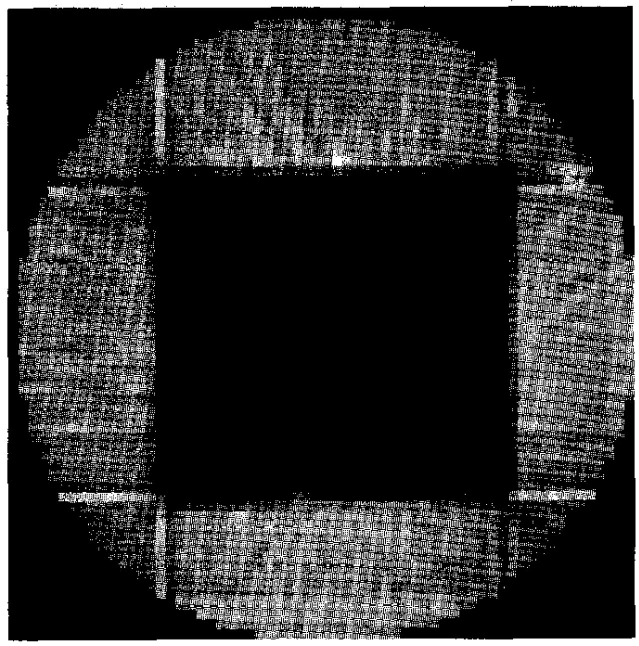

Figure 11. Enlarged image for sample 3

As CT is the imaging technique which provides complete object visualisation in terms of cross-sectional details, thereby making it possible to resolve all internal details in their true perspectives. Hence as far as CT images are concerned, the focus remains mainly on enhancement of features, and reduction in reconstruction artifacts rather than on magnification of the image without pixalisation. Hence, the complete object visualisation is achieved only when the originally acquired dataset is interpolated (i.e., filling the gap in between the data or generating additional data.) to get an enlarged dataset. The reconstructed image using this enlarged dataset shows the enhanced image visualisation in CT images. Thus, this technique could even bring out the features which otherwise were not visible with a limited dataset. Moreover, this enlarged dataset can be further enlarged by applying same interpolation technique exploring the possibility of further enhancement in image visualisation. Hence it is clear that unless the originally acquired data itself is operated upon, the reconstructed image may not show the features which were not present in the original image. Therefore, the interpolation technique through sinogram is certainly better and more so in the case of CT image visualisation. In the visualisation of images, where main emphasis is only on magnification of the image, enlargement through sinogram will not be required.

5. CONCLUSION

The study establishes that enlargement of one-dimensional parallel projections for image reconstruction using interpolation operators can be utilised to improve the quality of image and reduce the data acquisition time considerably. The quality of the image is improved in terms of enhancement of features, reduction of reconstruction artifacts as well as magnification without pixelisation, and thereby enhancing image visualisation in CT images.

The enlargement procedures based on this technique have potential to be applied for any of the three requirements, viz., for enlargement of projections keeping the number of rays per projection as constant, for enlargement of only the rays per projection and keeping the number of projections as constant, for enlargement of number of projections as well as the number of rays per projection. Further improvement in the quality of image can be achieved using a variety of filters at different stages, i.e., starting from the formation of the sinogram up to the final reconstructed CT image which may bring better results.

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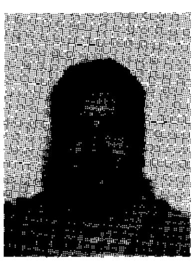

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