Progressive image transmission in telemicroscopy

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Telemicroscopy provides access to expensive and unique microscopes available in a few research centers, allowing multiple remote users to control the instruments in real time and acquire the images from the current experiment [1]. A telemicroscopy system essentially consists of two components: the microscope-server and the telecontrol clients. The server is in charge of receiving microscope operation and image-capture commands from clients, executing these commands, and distributing the image files to the requesting clients. The clients can remotely control automated features of the microscope, including focus, stage position, magnification, etc. Several telemicroscopy systems have been already introduced in the fields of structural biology and medicine [2,3,4].

Image compression plays an essential role in telemicroscopy to minimize latencies, allowing real-time control of the microscope and fastening image acquisition at the client. Most of the current telemicroscopy systems use the standard JPEG compressor/decompressor [2,3,4] to reduce the size of the image to be transmitted. However, images transmitted with JPEG are transmitted row by row, and in most cases only when the full-sized image has reached the client, the user can adjust microscope settings. This problem can be only partially solved using the progressive mode of JPEG, where users receive a reduced number of incremental quality versions of the image. In any case, the main drawback is that JPEG is a lossy compressor, so it is not possible to exactly reproduce the original image from its JPEG version at the clients.

Progressive image transmission is very suitable and more convenient for telemicroscopy as shown in [6]. It basically consists of a wavelet-based hierarchical multiresolution representation of the image, and a progressive-fidelity encoding stage. The former concentrates the most relevant information into a few wavelet transform coefficients, while the latter transmits the coefficients in decreasing order so that the error with respect to the original image is minimized. As a result, progressive image transmission allows, from the very beginning, visualization of a full-sized image that is an approximate version of the original one. Further, every element of the progressively transmitted data contains information for refining the image globally, instead of locally as a non-progressive transmitter does. This behaviour makes progressive transmission very suitable for telemicroscopy since the most valuable visual information is transmitted first, and transmission times of full-sized images are minimized, thus facilitating remote control of microscope. Finally, since this is a lossless compression, it is guaranteed that the image at the client at the end of the transmission is an exact replica of the image obtained by the microscope.

In this work we are using the recent JPEG2000, which is becoming the standard for image transmission. It is a lossless (reversible) codec that supports progressive recovery by fidelity [6] and resolution, static (at encoding time) ROI (Region Of Interest) coding and error resilience. Further, it also supports some basic operations that can be done efficiently on coded images such as cropping, horizontal/vertical flipping and rotation by an integer multiple of 90 degrees. The cropping feature allows a remote browser to receive only a portion of the compressed code-stream and reconstruct the desired ROI, on demand (see Figures 1 and 2). Thus, the interactive retrieval of specific areas in large images allows us to reduce dramatically the time necessary to remotely control the microscope.

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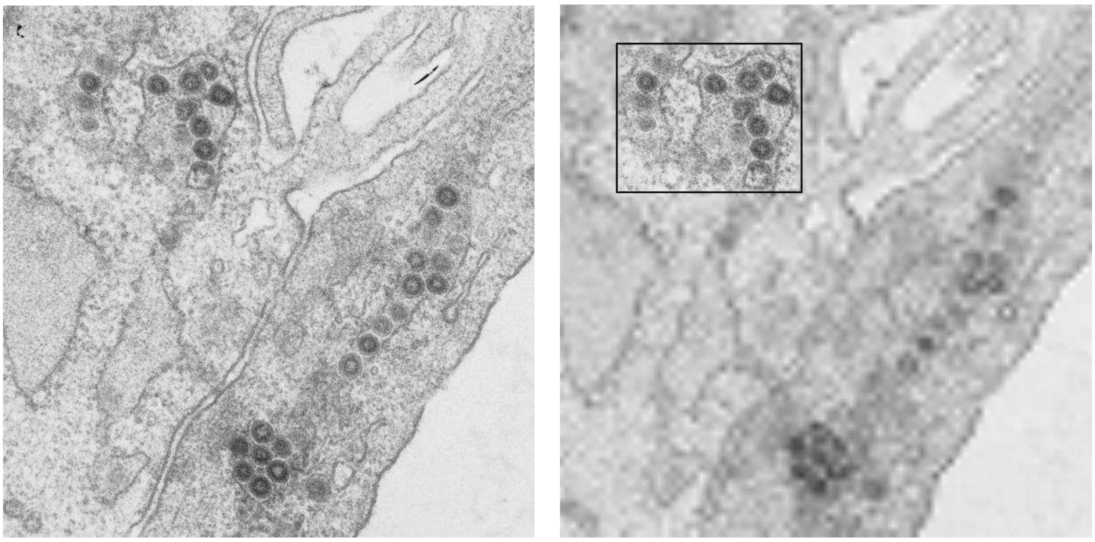

Figure 1. Reconstruction of a TEM image of transmissible gastroenteritis coronavirus at a remote client. Left: Original image obtained from a TEM. Right: Image reconstructed at the client after receiving 0.1 bits per pixel (i.e. 12.5% of the total size of the original image at the server). In this test, a ROI was selected from the image (see rectangle in the picture on the right). It is clearly observed that the difference between the ROI in the original image at the server and the reconstructed ROI at the client is visually negligible.

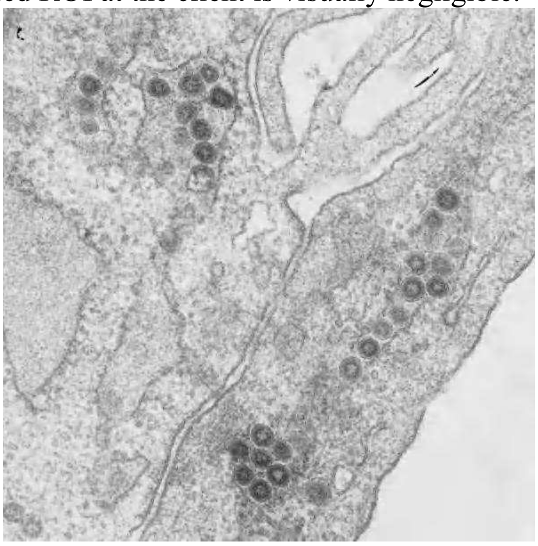

Figure 2. The same image in Figure 1 is shown as reconstructed with 0.1 bits per pixel without any ROI selected.