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FRACTIONAL DIFFERENTIAL PROCESSING FOR MEDICAL IMAGING

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INTRODUCTION

Medical imaging is often designated as being a sub-discipline of biomedical engineering, devoted to the study of non-invasive techniques, to obtain images of internal aspects of the body. Radiology, ultrasonography and magnetic resonance are well-known techniques: as all the techniques of medical imaging, they comprise both technical aspects of data acquisition and problems connected with diagnostic interpretation. As a consequence, imaging turns out to be a valuable means to infer the properties of living beings from their effects, that is the observed signals.
Quality of images is therefore fundamental, to have the possibility to increase details with respect to the background. There are many resources useful for processing images, most of them freely available and quite friendly to use. In spite of this abundance of tools, the development of new processing methods is still worthy of efforts. Here, we are proposing a tool based on the use of fractional differential calculus for enhancing and restoring image quality.

FRACTIONAL GRADIENT METHOD

Fractional differentiation has started to play a very important role in various research fields, also for image and signal processing. Algorithms for image manipulation based on the discrete implementation of generalized derivative and integration of functions to non-integer order have been proposed [1-3]. Here we show an approach based on the fractional gradient. Assuming the image described by a two-dimensional map $s(x,y)$, where x,y are the discrete positions of pixels, the components of fractional gradient are defined as:

$$\begin{aligned} G_x^\nu(x,y) &= s(x,y) - \nu\, s(x-1,y) - (1/2)\nu(1-\nu)s(x-2,y) - (1/6)\nu(1-\nu)(2-\nu)s(x-3,y) + \ldots \\ G_y^\nu(x,y) &= s(x,y) - \nu\, s(x,y-1) - (1/2)\nu(1-\nu)s(x,y-2) - (1/6)\nu(1-\nu)(2-\nu)s(x,y-3) + \ldots \end{aligned} \qquad (1)$$

with ν real number. In the case that ν = 1, we have the usual first-order partial derivatives. Calling $G^\nu(x,y)$ the magnitude of the fractional gradient and finding its maximum value G^ν_M in the image map, we define an output map $b(x,y) = 255(G^\nu(x,y)/G^\nu_M)^\alpha$, where α is a parameter suitable to adjust the image visibility (for details, see [4,5]). The software to create this output image is contained in a tool, the *ImgFracTool*. To the authors' knowledge, this is the first free digital imaging software package using routines based on fractional calculus.
ImgFracTool works on any BMP or JPG image. The package is running on Windows NT/2K with a .NET free package and freely downloadable from the web site: http://staff.polito.it/roberto.marazzato/imgfractool.zip. The interface is quite simple: it is possible to open a selected image and set the processing parameters and choose the image to be displayed. There is also the possibility to create a HTML report (the use of which is strongly suggested for recording purposes), editing the most relevant data of the last report.

RESULTS AND DISCUSSION

ImgFracTool creates the output map using two processing parameters: the order of the fractional derivatives (ν) and the adjustable image visibility exponent (α). Fractional parameter ν is suitable to enhance image edges, whereas brightness and contrast are improved by means of parameter α. This further processing does not add or remove information. After testing the algorithm on several images, we suggest that fractional gradient could properly enter those image-processing tools devoted to the detection of faint objects and details. We noted in fact an enhancement of faint textures in the image, that are depending on the density matter variation. Two examples are shown in Fig.1 and 2.
Note the embossment effect, giving a three-dimensional effect to the image. Future works are needed, adding the algorithm with new possibilities. An interesting processing feature could be the comparison

of images (addition and subtraction of images). As a matter of fact, the use of this tool by medical operators will be very useful to prepare the new versions. Suggestions to improve the software according to the needs of the intended users are welcome.

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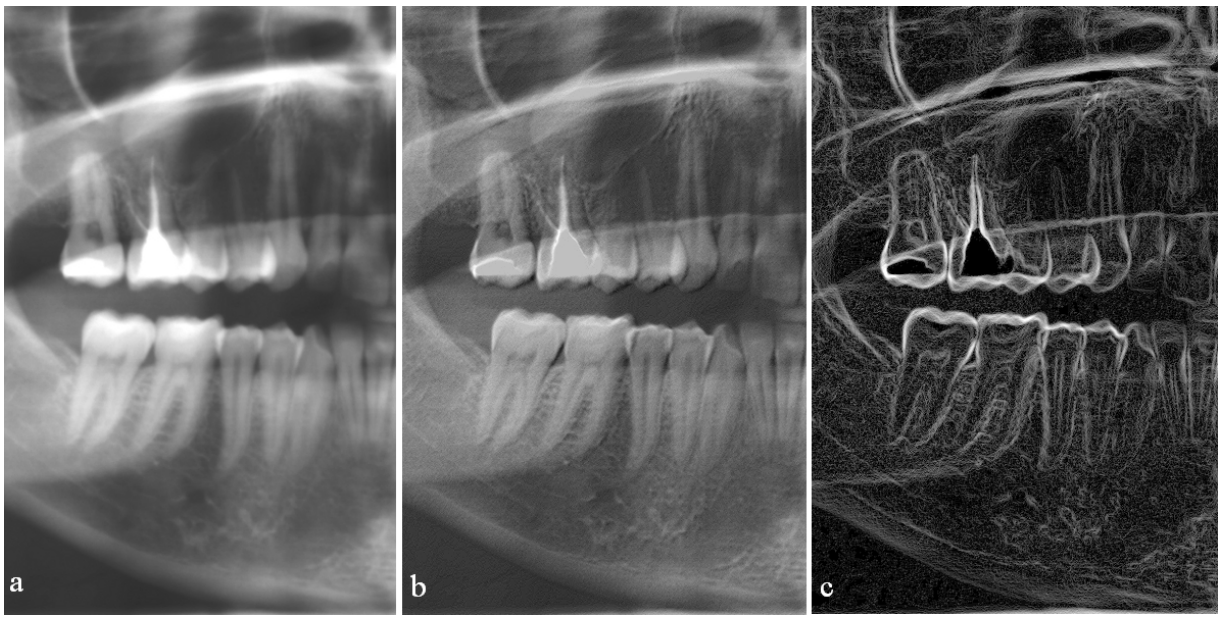

Fig.1 Original X-ray image (a) and images obtained applying *ImgFracTool* with three different values of increasing fractional parameter and adjusted visibility (b,c). Note embossment effects on the roots of teeth.

Fig.2 A magnetic resonance image (left, author Nevit Dilmen) and the *ImgFracTool* image (right). The image shows again an embossment effect.