An application of the Phase Stretch Transform for extraction of *Mycobacterium Tuberculosis* colonies in MODS images

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Introduction: Tuberculosis (TB) is a deadly disease caused by the bacteria *Mycobacterium Tubcerulosis* (MTB). Among many diagnostic methods for it, the Microscopic Observation Drug Susceptibility assay (MODS) developed in Universidad Peruana Cayetano Heredia is an interesting alternative, with a similar cost, sensitivity and sensibility, and a shorter time to diagnosis [1], than other culture-based tests. An image processing method [2] with a sensibility and sensitivity of up to 95% has already been developed. In this context, a segmentation method based on the Phase Stretch Transform [3] followed by binarization and morphological operations is applied for MODS images.

Methods: The image segmentation method begins with and edge enhancement step based on the Phase Stretch Transform (PST):

$$\boldsymbol{I_{PST}}(x,y) = \angle\{IFFT_{2D}[\widetilde{\boldsymbol{K}}(u,v)\cdot\tilde{\boldsymbol{L}}(u,v)\cdot FFT_{2D}(\boldsymbol{I}(x,y))]\} \dots (1)$$

Where $\boldsymbol{I}(x,y)$ is the grayscale MODS image, $\tilde{\boldsymbol{L}}(u,v)$ is a low-pass Gaussian filter (localization kernel) with bandwidth Δf and $\widetilde{\boldsymbol{K}}(u,v) = e^{j\boldsymbol{\phi}(u,v)}$ is an all-pass, non-linear phase filter (phase warp kernel). The utilized non-linear phase is the same as in [3]:

$$\boldsymbol{\phi}(u,v) \rightarrow \boldsymbol{\phi_{polar}}(r,\theta) \rightarrow \boldsymbol{\phi_{polar}}(r) = S\frac{Wr\tan^{-1}(Wr) - \frac{1}{2}\ln[1+(Wr)^2]}{Wr_{max}\tan^{-1}(W\,r_{max}) - \frac{1}{2}\ln[1+(Wr_{max})^2]} \dots (2)$$

Where S is the stretch of the transform, and W is its warp. After applying the transform, the image $\boldsymbol{I_{PST}}(x,y)$ is segmented by its intensity values with a global threshold computed by Otsu's method [4], and the resulting image is morphologically closed, opened, then closed and opened again, resulting in a binary image $\boldsymbol{I_B}(x,y)$ with the extracted regions of interest. The first closing is done with a rectangular structuring element of 10x10 pixels; the first opening, with a circular structuring element of radius 5 pixels; the second closing, with another rectangular element but with twice the size of the first one; and the last opening with a circular element of radius 7 pixels.

Results: Preliminary results show that the image segmentation method can adequately extract the foreground objects, among which the MTB MODS colonies are found. The evaluation of the proposed procedure was done by manually evaluating the segmentation in images of the last 5 days from four different MTB MODS cultures, and looking for either over-segmentations, under-segmentations, correct segmentations or missed objects. In general, the segmentation is more successful in the earlier days, where the colonies are smaller, with 60%-70% of correct segmentations – the other objects were either over- or under-segmented. The percentage of missed objects is typically around 15%,

Conclusion: The proposed method adequately extracts the desired regions. This has many potential applications, such as segmentation of irregularly shaped bacterial colonies and fast segmentation of non-uniformly illuminated scenes.

References: [1] Caviedes L, *et al*. Rapid, efficient detection and drug susceptibility testing of Mycobacterium tuberculosis in sputum by microscopic observation of broth cultures. Journal of clinical microbiology 2000, 38(3), 1203-1208.

[2] Alva A, *et al.* Morphological characterization of Mycobacterium tuberculosis in a MODS culture for an automatic diagnostics through pattern recognition. PLoS One 2013, 8(12), e82809.

[3] Asghari MH, Jalali, B. Edge detection in digital images using dispersive phase stretch transform. Journal of Biomedical Imaging, 2015, 6.

[4] Otsu N. A threshold selection method from gray-level histograms. IEEE transactions on systems, man, and cybernetics 1979, 9(1), 62-66.