Detection of microtubules and other fibrous structures by image analysis and virtual reality

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Microtubules (MT) are cylindrical cytoskeletal polymers indispensable for many vital cellular activities such as maintenance of cell shape, division, migration and ordered vesicle transport powered by motor proteins. Methods for detection of microtubules and other fibrous structures such as blood capillaries acquired by confocal and STED microscopy were developed. The tools were designed for detection of either well-separated fibres in images with low contrast or for poorly separated fibers in high contrast images. Well-separated fibres were represented by capillaries (Fig. 1a). We developed fibre enhancing filter based on calculation of local first and second moments (Fig. 1b). Our method, unlike the standard tubeness or featurness, has nonmax suppression property. The filtered image is thresholded after background subtraction, skeletonized and linear model of capillaries is then constructed (Fig. 1c). For detection of poorly separated fibers, such as microtubules, we applied automated tracking procedure: Microtubules (Fig. 2a) were sampled by pairs of parallel lines and local maxima of cost function of optimal paths between points located on the lines were calculated (Fig. 2b). The paths were merged to create MT models and also used for MT length density and orientation measurement.

In order to check the detection algorithms described above, 3D microscopic images of MT and capillaries were rendered using virtual reality (VR) and detected interactively. VR is being used for professional purposes for last two decades, but just recently it has become accessible to common users and is being standardized. We have developed a custom-made VR image analysis software, which is capable of rendering very high resolution VR image to high end enterprise head mounted display developed by VRgineers. Goggles are tracked using absolute position tracking system developed by DTrack. Application renders images to the virtual space around the user, where he is able to move and interact using his own hands or specialized controllers with rendered 3D reconstruction of acquired microscopic images. Acquired microscopic images of fibrous microstructures are converted into a volumetric object, which is then rendered to each eye using raycasting technique. Application is developed in .Net framework and DirectX 11 considering optimized algorithms for fluent visual perception.

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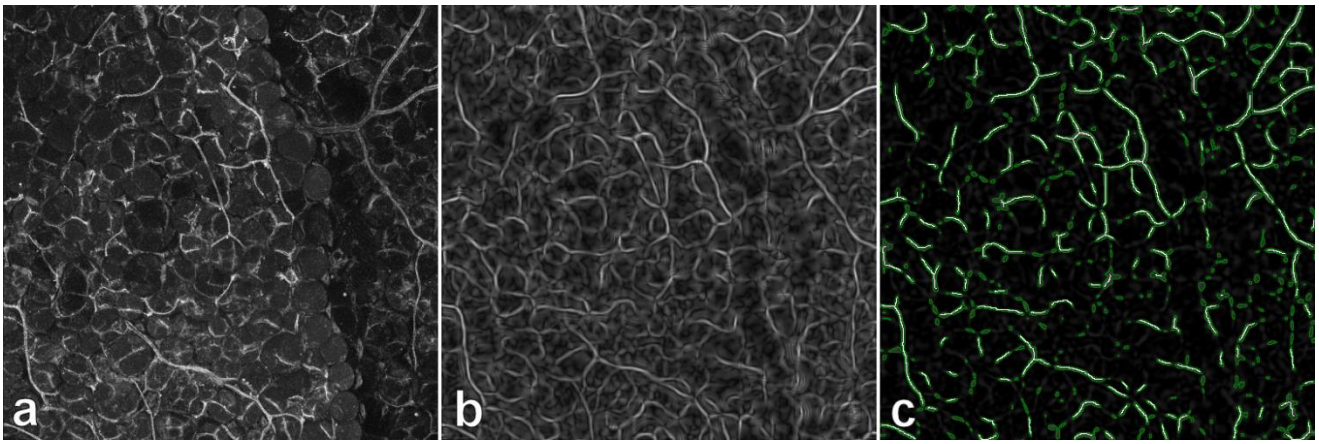

Fig. 1. Blood capillaries in adipose fat tissue. (a) Original 3D confocal microscopic (maximum projection of 40 optical sections). (b) After application of fibre enhancing fiter. (c) After thresholding and skeletonization and construction of linear model of capillaries.

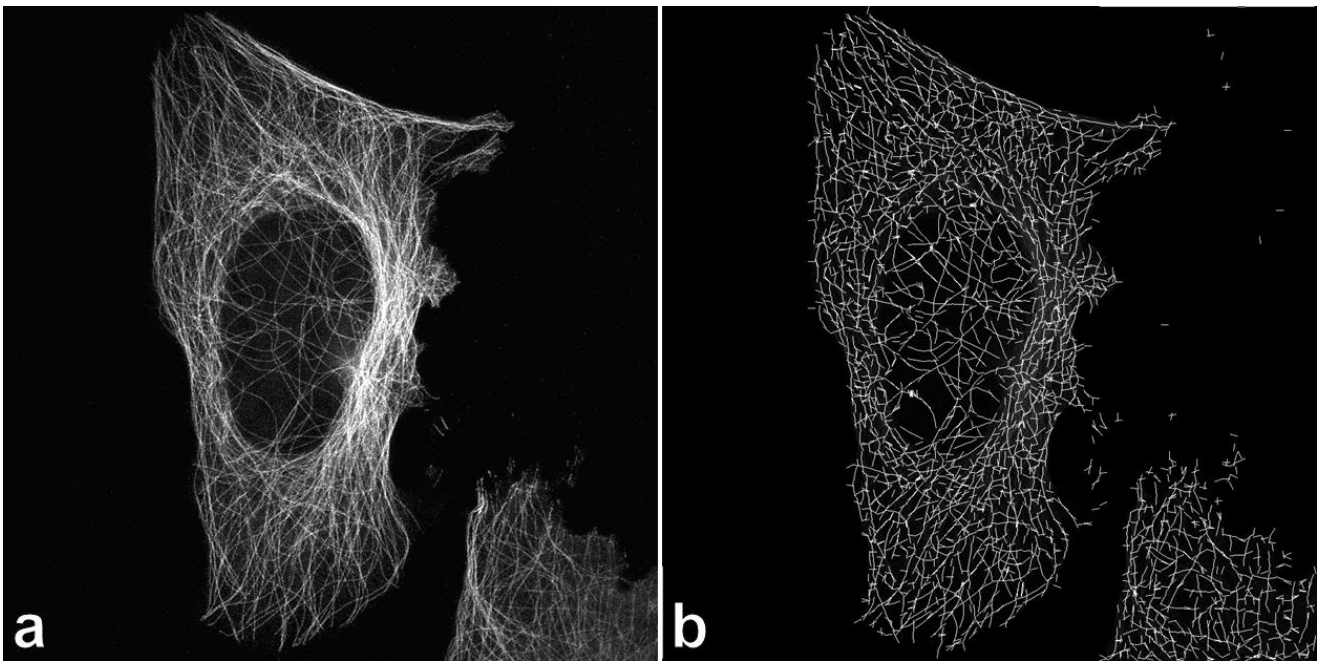

Fig. 2. Microtubules in human osteosarcoma cell U2OS. (a) Original STED image. (b) After application of automated tracking procedure.