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Computing Local Thickness of 3D Structures with ImageJ

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The local thickness described by Hildebrand and Rüesgsegger can characterize a 3D binary image of a complex structure such as a bone, a cell, or a paper fiber [1]. Such images are available from, for example, micro-computed tomography [2]. Let $\Omega \subset R^3$ be the structure. The local thickness at point $p \in \Omega$ is the diameter of the largest sphere that contains *p* and is completely inside the structure.

The problem is to transform the 3D binary image into the 3D local thickness image. Several steps to are given in [1]. The first is a Euclidean distance transformation (EDT) The distance map at $q \in \Omega$, $D_{\text{map}}(q)$, is the distance from *q* to the nearest background point. The sphere of radius $D_{\text{map}}(q)$ centered at *q* is completely inside the structure. If *p* is within this sphere, then the local thickness at *p*, $t(p)$, is at least $D_{\text{map}}(q)$. Points *q* are scanned to find $t(p)$ by maximizing this bound. A further simplification is to first remove many of the points whose spheres of radius $D_{\text{map}}(q)$ are completely contained within the corresponding spheres of other points. Removing all of the redundant points would produce the distance ridge (DR) which is related to the skeleton and the medial axis [1, 4].

A 3D local thickness procedure has been implemented in Java as a plugin for ImageJ [5]. The EDT uses the fast algorithm given by Saito and Toriwaki [6]. The DR computation is a simplified form of a template scheme [7]. Care was taken to optimize the use computational resources. No temporary 3D buffers are required. A related implementation in C was given previously by Coeurjolly [8]

An example using a microtomographic dataset of a root canal is shown in Figures 1-2. The complete computation (342 × 254 × 669 pixels) required 38.8 seconds PC.

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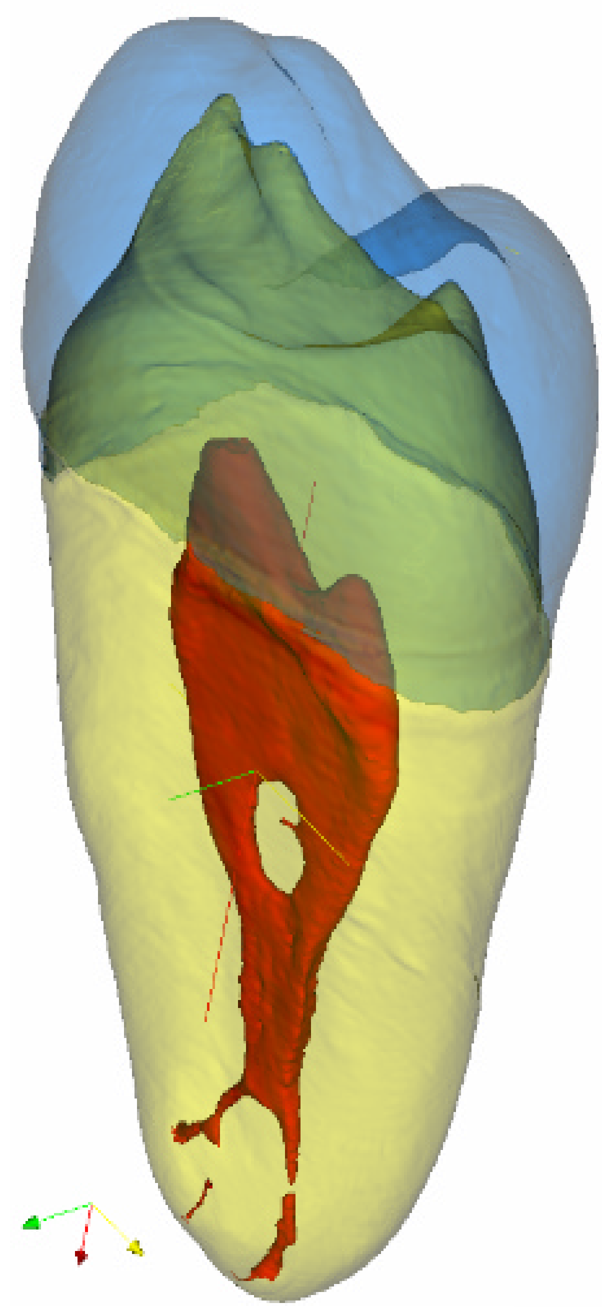

Figure 1. The original 16bit data from the microct were segmented into enamel, dentin and the pulp tissue based on their different radiographic absorption. Enamel is rendered in cyan, dentin in yellow and the pulp is visualized in red with ParaView 2.4 (Kitware, www.kitware.com).

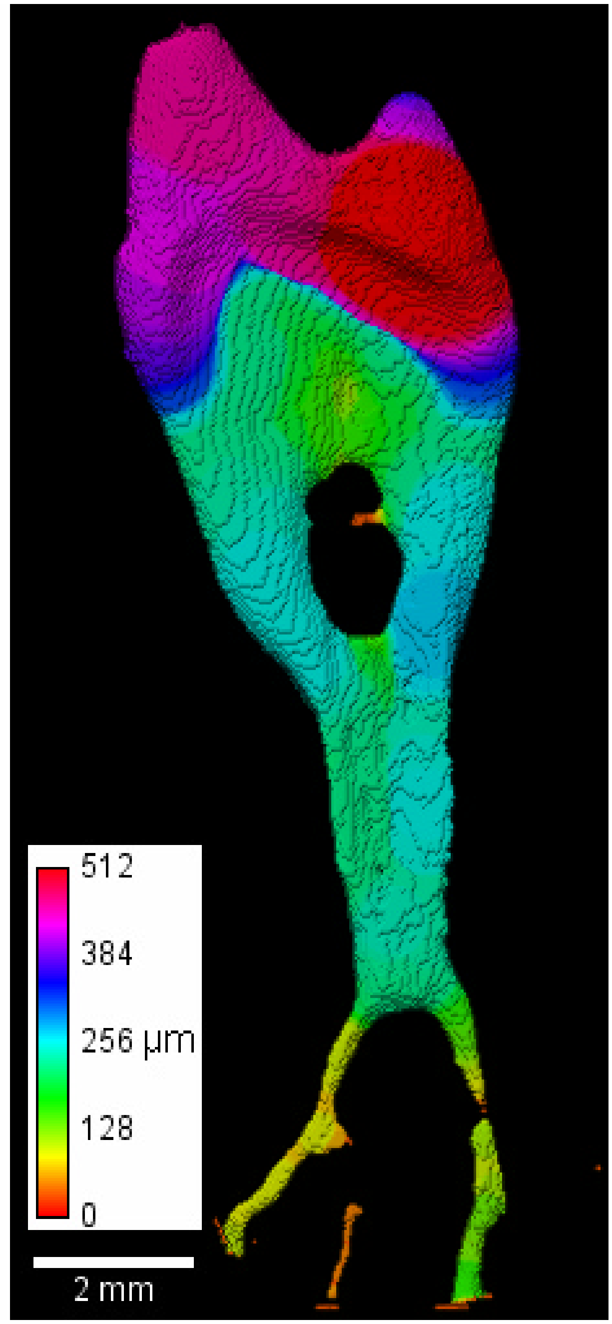

Figure 2. The segmented pulp volume rendered with the VolumeJ plugin for ImageJ (v. 1.7a, Michael Abramoff). The local thickness is mapped to the surface of the pulp. This information is used to develop optimized root canal instruments (diameter and taper). During a root canal treatment infected tooth tissue has to be removed. The goal of an endodontic treatment is to keep the original shape of the pulp canal, but instrument it down to the apex without obliteration and without iatrogenic damages.