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# *SKELETONIZATION ALGORITHM USED IN VIRTUAL COLONOSCOPY ADAPTED TO THE ANALYSIS OF SEAL TEETH IN ARCHEOLOGY*

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**Summary:** A skeletonization algorithm used in virtual colonoscopy to define the navigation path has been adapted to analyse fossil seal teeth found in Greenland. A solution using 3D tools was used to solve a 3D problem: distance transform and virtual spheres were used to generate skeletons. Density, curvature and diameter profiles along the skeleton were computed and used to describe 126 teeth samples. The complex shape of teeth was revealed and studied.

## 1. INTRODUCTION

Skeletonization is a process used to extract morphological information about objects. Many algorithms exist [1] and are designed for different purpose such as visual inspection, fingerprint and optical character recognition. In this study, an algorithm designed to extract the centre-line, the skeleton, of a human colon as a flight path for virtual navigation [2] in virtual colonoscopy has been adapted to study archaeological marine mammal teeth found in the medieval Norse settlements of western and southwestern Greenland. The benefit of this algorithm is a low computational cost: medical environment requires fast diagnostic tools. The samples are harp seal and grey seal teeth dated from $10^{th}$ to $13^{th}$ century AD. Inner cavity volume is directly related to the age of the specimen at the end of his life. Common tools were unable to measure their shape as they present multiple curvatures and inner cavity was not accessible. Thus, a total of 126 teeth samples were digitize using a medical CT-scanner at the INRS CT-scan multidisciplinary laboratory for non-medical use. Adults and child specimens were analysed to describe their density, cavity and shape.

## 2. EXPERIMENTAL METHOD

A Siemens Somatom Defintion AS+ has been used for teeth scanning. Samples were laid on a carbon fibres examination table. As the CT-scanner is mounted on a sliding gantry, the examination table stand still while the CT-scanner performs spiral scanning. The scan acquisition parameters were: 120kV, 300mAs, 1s rotation time and a pitch of 0.3. For the image reconstructions, the kernel V90u (a sharp filter) was selected and three reconstructions iterations has been performed using Siemens SAFIRE algorithm (Sinogram Affirmed Iterrative REconstruction) [3]. Images slices had a pixel resolution of 0.1x0.1x0.4mm$^3$. A total of four hours was needed to scan 126 samples. MATLAB software was used for image processing and implementation of the skeletonization algorithm.

The first phase of the skeletonization algorithm is to compute a 3D Euclidian distance transform of the object. Then, a first sphere is numerically inserted at the location where the maximum distance, which defines the sphere diameter, is found. Positions of the sphere volume are removed from the 3D distance map as possible candidates for the next sphere position. Then the process is repeated until no more spheres can be added. Incorrect spheres are removed based on different criteria like the number of neighbours and inconsistent position. Subsequently, the spheres centre of gravity locations are sorted from one end to the other so a continuous line can be drawn along

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the sphere path. Each sphere is connected to its closest neighbour until no more spheres are available. Finally, interpolation between points is performed and an extrapolation is used to bring the centre line to the tips of the object.

Once the skeleton is completed, one can derive shape information along the teeth. A continuous local curvature profile is derived and the sample diameter is measured at each skeleton position using ferret diameter. A density profile at the centre line is also extracted and used to describe the length of the cavity.

## 3. RESULTS

Density, curvatures and Ferret diameter profiles have been extracted. First, density profile gives indication about the presence or absence of diseases. Then the tooth cavity can be described in terms of volume but also in terms of length and diameter using profiles along skeleton. Finally, curvature profile shows how complex the tooth shape is [1b]: peaks and plateaus indicate transitions from one curve radius to another. Statistics on the curvature shows promising avenue to assist in telling the story of each sample. In addition, a global approach can provide correlation about the region where it was found, diseases and age at the end of animal life.

The skeletonization algorithm was well suited for teeth samples and performed rapidly. To be able to automatically and quickly analyse a large amount of similar archaeological samples is a great advantage. It provides to researchers robust statistics about their archeological sites and, in the case of teeth, new type of information that was not accessible before.

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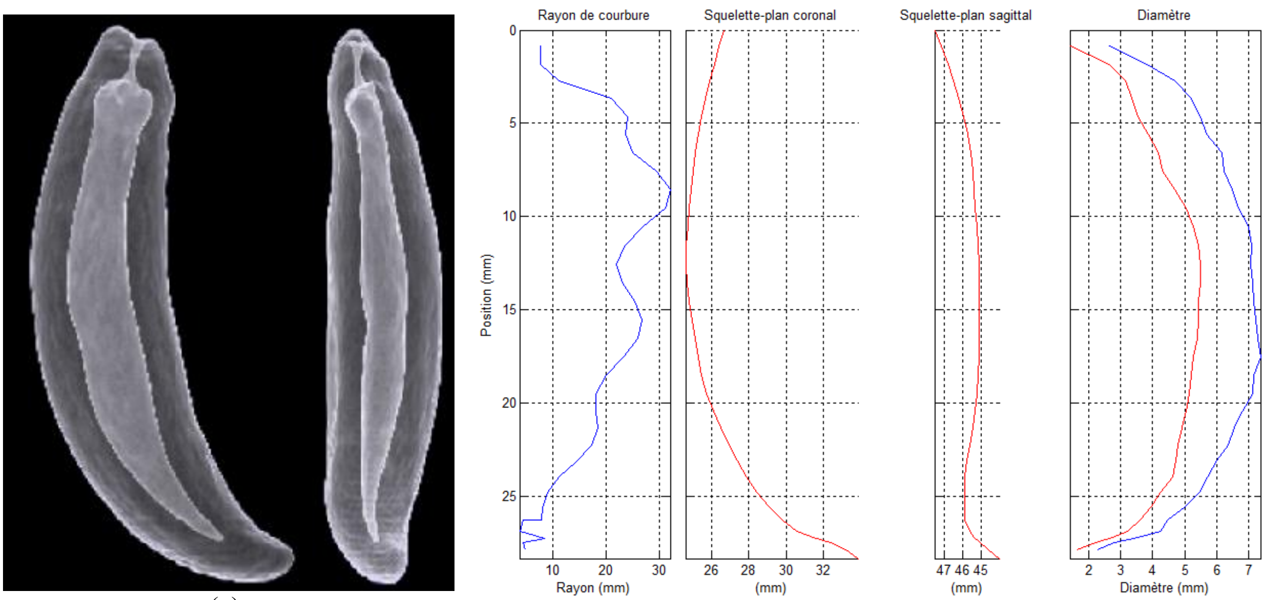


(a) (b)

**Figure 1:** (a) Coronal and sagittal MPR rendering of the tooth #25. The cavity is clearly visible. (b) Curvature profile, skeleton coronal and sagittal views and Ferret diameter (minimum and maximum) profile are shown.