DTU Informatics
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Removing that annoying hair growth!

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Abstract

In the future custom fitting a hearing aid will be without unpleasant impression taking. Instead the ear canal will be scanned using a 3D scanner. With data from a new scanner prototype our work deals with the problem of removing structured noise from hair in such scans and create good plausible surfaces.

Motivation

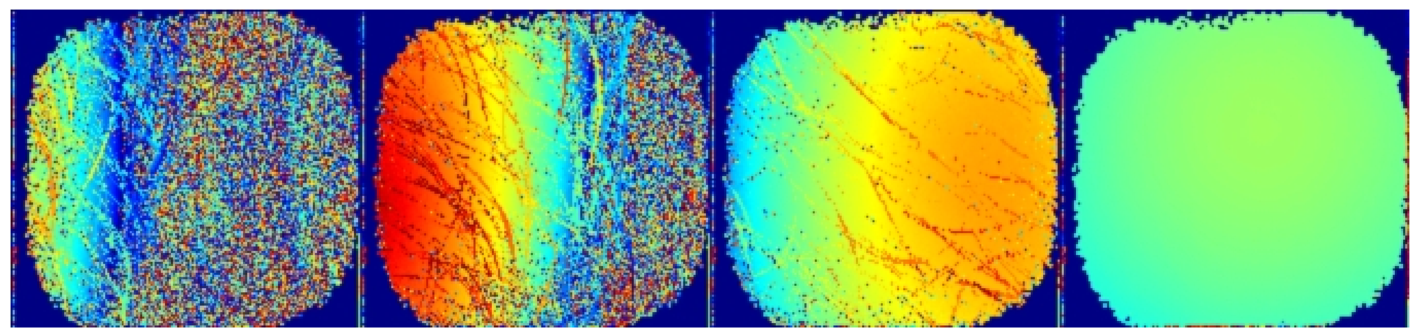
If the ear canal could be scanned with high precision and robustly modelled in 3D, then the process of creating a custom fitted hearing aid would be a lot easier and quicker. It would also mean less discomfort for the patient, as there would be no impression taking.

Problem

A prototype that will fit in, and be able to scan, the ear canal is under development at 3Shape. The main source of noise in such scans will come from hair. This structured noise is the focus of our work.

Data

As the prototype is not yet fully functional, we have worked with data from its older sibling; a newly developed scanner for digital impression taking in dental clinics. Build on a similar principle this scanner uses an ultra fast image sensor and rapid changes in a proprietary optical system to extract 2.5D surfaces. Below are depthmaps from four different scans ranging from little surface coverage and a lot of hair to full surface coverage and no hair. The algorithm should handle all cases.



Markov Random Field volume classification

We want to find the data points that belong to the skin in order to remove the rest (hair and noise) from the point set.

A scan surface is placed in a voxel volume (row,col,depth) such that only one scan point exists along the depth axis for each row,col-coordinate. The volume is considered a 3D Markov Random Field.

To classify the voxels v_i in the volume as being *above* or *under* skin surface the following energy minimization problem is solved:

$$E(\boldsymbol{x}) = \sum_{i \in I} \left(\Phi(v_i|x_i) \sum_{j \in N_i} \left(\lambda(x_i, x_j) + \psi(x_i, x_j) \right) \right)$$

Where $\boldsymbol{x}$ is the classification of the volume with index I and N defines a local neighbourhood. The likelihood function:

$$\Phi(v_i|x_i) = -\log P(v_i|x_i)$$

Where the probability $P(v_i|x_i)$ is high if x_i is labelled *above* skin and v_i is also over the scan surface, it is also high if both are under. The probability is low if the relative position and label does not match. The first neighbourhood term is:

$$\lambda(x_i, x_j) = \begin{cases} K_{dist} * \mathrm{dist}(v_i, S_{scan}) & x_i \neq x_j \\ 0 & x_i = x_j \end{cases}$$

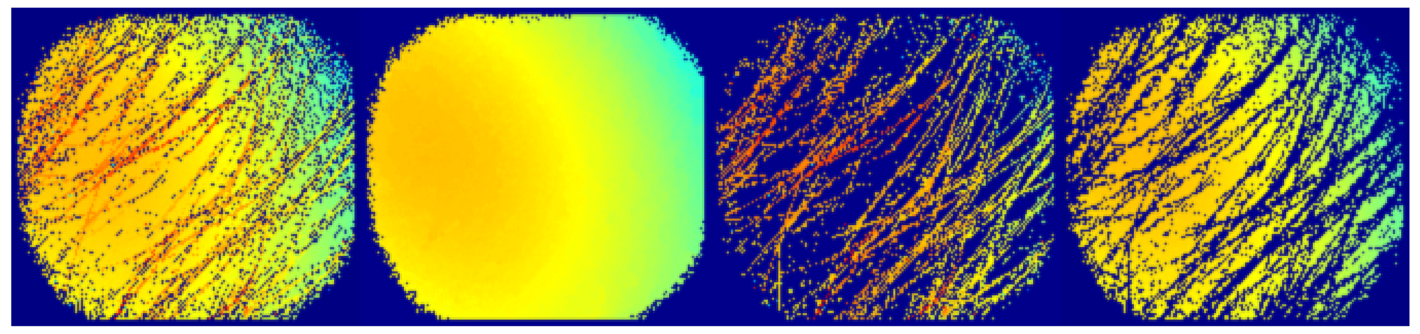
This term forces label changes (the surface) to be close to scan point but it also penalizes discontinuity. The second neighbourhood term is a simple smoothness prior:

$$\psi(x_i, x_j) = \begin{cases} K_{ij} & x_i \neq x_j \\ 0 & x_i = x_j \end{cases}$$

The minimization problem is solved using a *Graph Cut* algorithm and a new surface S_{MRF} is found in the intersection between labels. The found surface is used to classify the original scan surface:

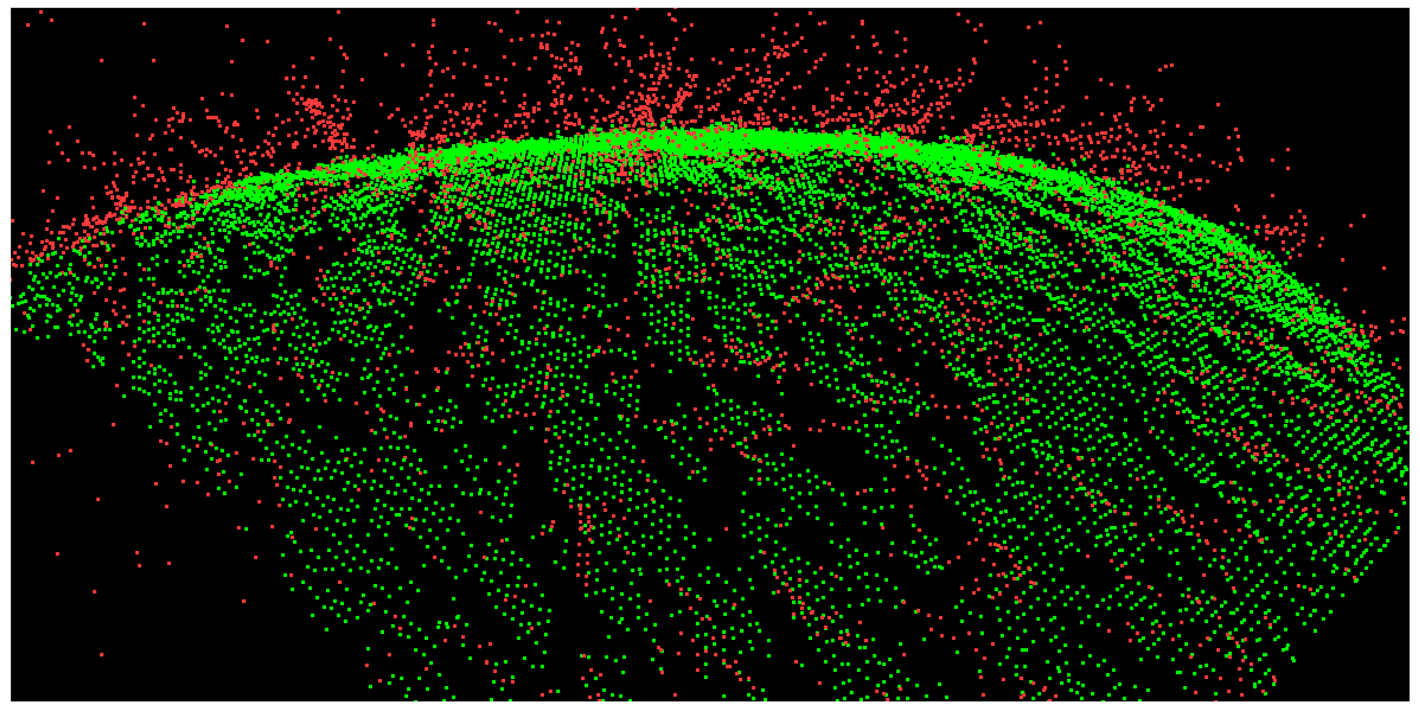
$$S_{skin} = S_{scan} \cap S_{MRF} \ \wedge S_{hair} = S_{scan} \setminus S_{MRF}$$

The skin/hair classification is shown below, where the first depthmap shows the original input, the second shows the MRF-surface followed by the classified hair and then skin.



Skin surface reconstruction

Having classified the data the *god* skin data can be used to reconstruct the skin surface. The following figure shows the classified data converted into real world coordinates through a calibration step.



Using only the skin data a surface is reconstructed using a *Markov Random Field Surface Reconstruction*. The promising result is shown below.