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A Goose Bump Detection System

Introduction

Goose bumps are a dermal phenomena that can result from a number of stimuli. Of particular interest is the response from great music. When music resonates for the listener, goose bumps are often observed. One could argue that goose bumps constitute a bio-signal that marks moments of inspiration. Goose bumps are qualitatively unmistakable to the observer, but a quantitative measure has not been developed. The goal of this work is to develop a method and device for quantitatively measuring goose bump expression.

Background

The Fourier transform is a mathematical process through which, the frequency components of a signal may be uncovered. By transforming the signal into the frequency domain, periodic trends can be detected. The autocorrilation of a signal can be measured by translating the signal over it's self. The process of measuring the overlapping area of the signal and it's self during the translation can indicate the memory of the signal.

Materials and Methods

Digital images were obtained of skin with and without goose bumps. The subject's forearm was illuminated at an acute angle (<20 deg) by a broad-spectrum light source. A control picture was taken (figure 1), then the music began. Classical music by Rachmaninoff was chosen because of its intense nature and particular interest to the subject. Once the music began, goose bumps were observed and another digital picture taken (figure 2). The appearance was accentuated by the shadows induced by the acute illumination.

The images were re-sampled and decreased (from 2048x1536 pixels to 532x399) in size to ease the computational requirements of the image processing routine. The files were converted to type double for numerical manipulation. The RGB pictures were converted to grayscale (figures 3 & 4) using the following equation:

Gray = 0.3*R + 0.59*G + 0.11*B

A set of pixels of constant y-value were sampled to yield a skin profile for both the goose bumps and control pictures as shown in figures 3 & 4 by black lines. Since we are only interested in the AC component in the signal variation over the lines, a linear fit the trend was established (figure 5).

The AC component was isolated (figure 6 a& b), by subtracting the linear fit from the data. Note that the x-axis is now in millimeters. The conversion from pixel number to physical position can be found in the appendix. Noise was then removed from the signals by implementing and m-point moving filter. The filter averaged the m neighbors of each pixel. The resulting profiles (figure 6 c& d), were analyzed for frequency components using the fast-Fourier transform (figure 7 a). The x-axis was converted to [mm^{-1}] as explained in the appendix. The signals were also analyzed using the x-covarience function (figure 7 b). Figure 8 shows a close up view of the memory of the system.

Analysis and Conclusions

It can be plainly seen in figure 7-a that goose bumps are detectable by measuring the spatial frequency = 0.2 [mm^{-1}] component of the Fourier-transformed signal. The data presented is only one sample for the purposes of demonstration, but in an additional analysis, a more statistically sound conclusion was drawn. 100 randomly distributed pixel samples were taken on each of two pictures. For each Fourier spectrum (as in figure 7-a) the peak frequency component of the goose bumps signal was found. The magnitude of the control sample's fft at the frequency component was also recorded. The mean and standard deviation for this data set is shown in figure 9. It can be seen that the presence of goose bumps can be determined by setting a threshold value and observing the frequency component at the goose bump frequency which appears to be 0.3467 [mm^{-1}] for the one subject measured.

In conclusion, goose bumps can be easily measured by examining the frequency component of a pixel sample from a skin picture that corresponds to the spatial frequency of goose bumps. As a check, the spacing of goose bumps should be the reciprocal of the frequency component that represents them. In figure 10, the goose bump figure is displayed with black lines corresponding to 1/0.3467=2.88 [mm]. It can be seen that this is an appropriate value for goose bump spacing, hence the algorithm was successful.

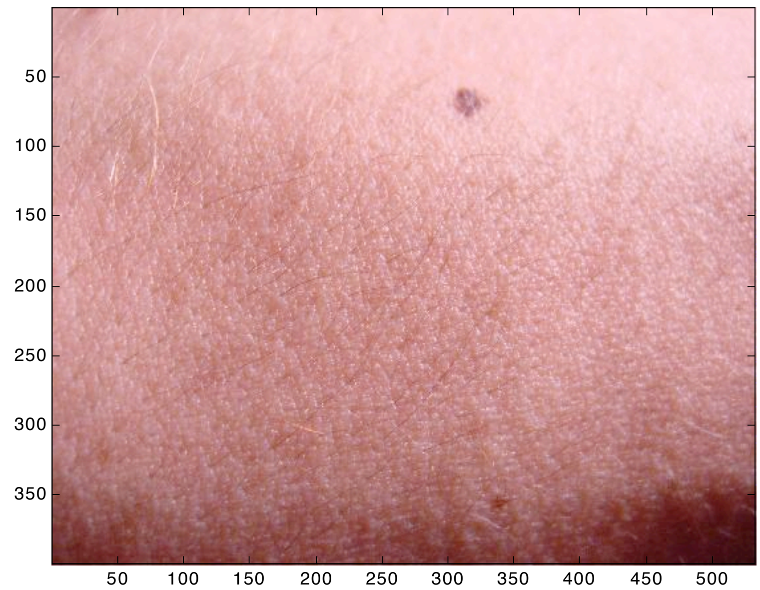


Figure 1 Normal Skin

Figure 2 Music-Induced Goose Bumps

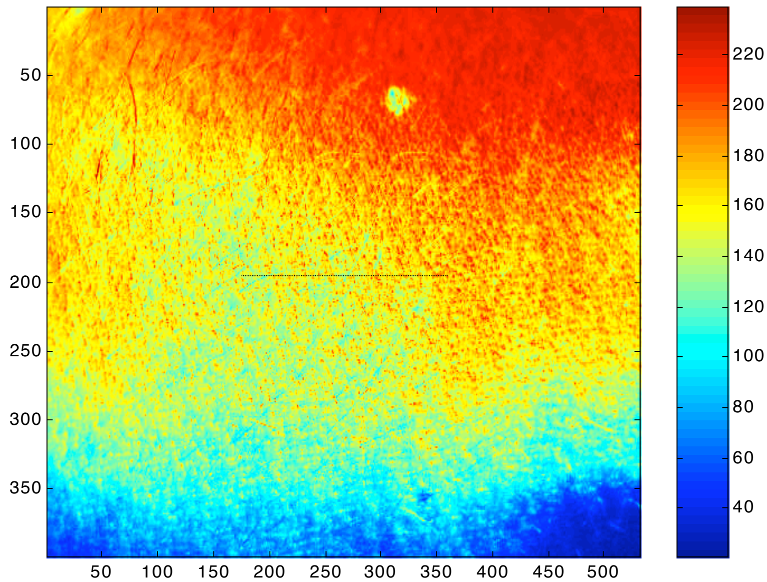


Figure 3 Gray Scale Normal Skin

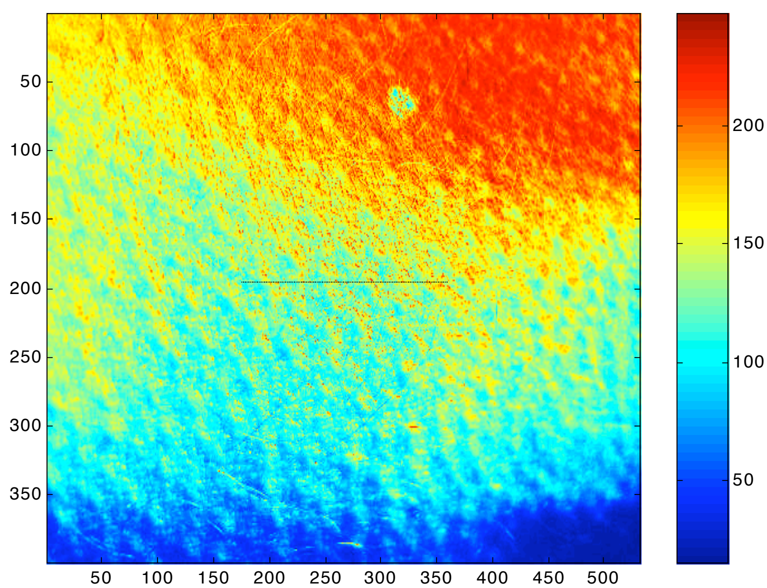


Figure 4 Gray Scale Goose Bumps

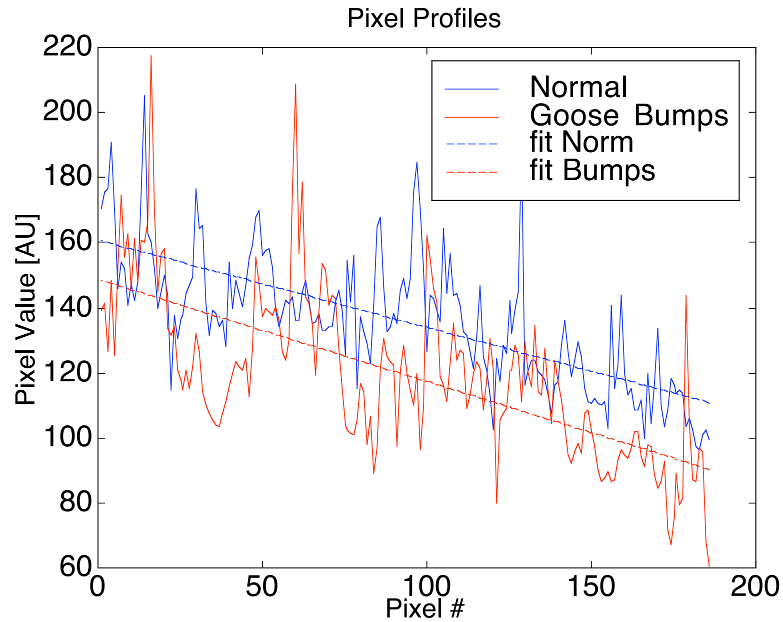


Figure 5 Pixel Samples and Their Linear Fits

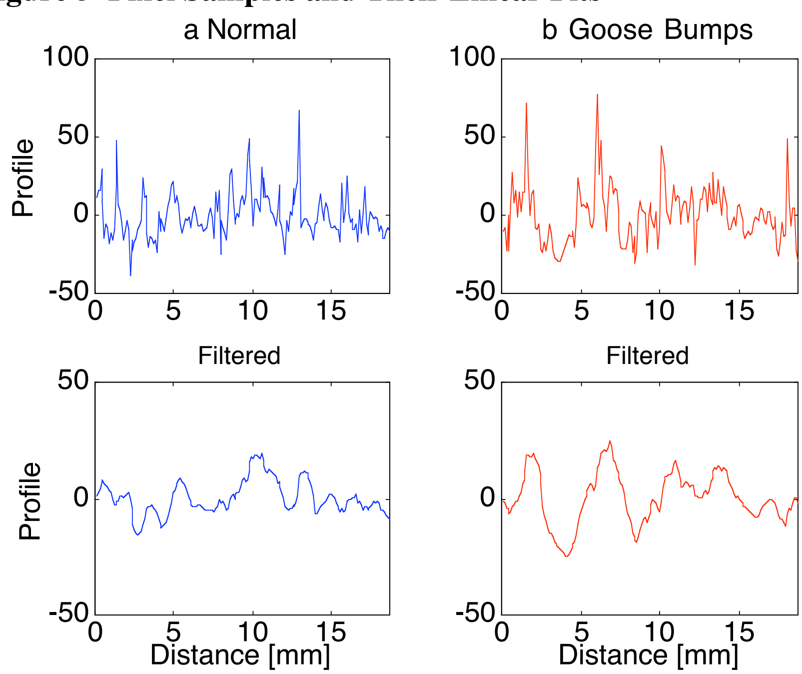


Figure 6 Implementation of m-Point Moving Filter

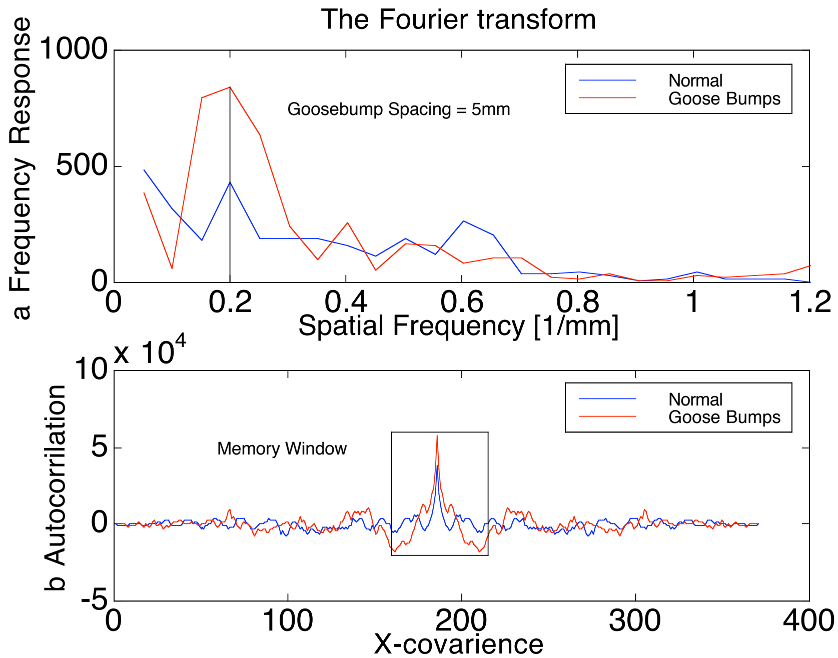


Figure 7 The Fourier Spectrum and x-covarience

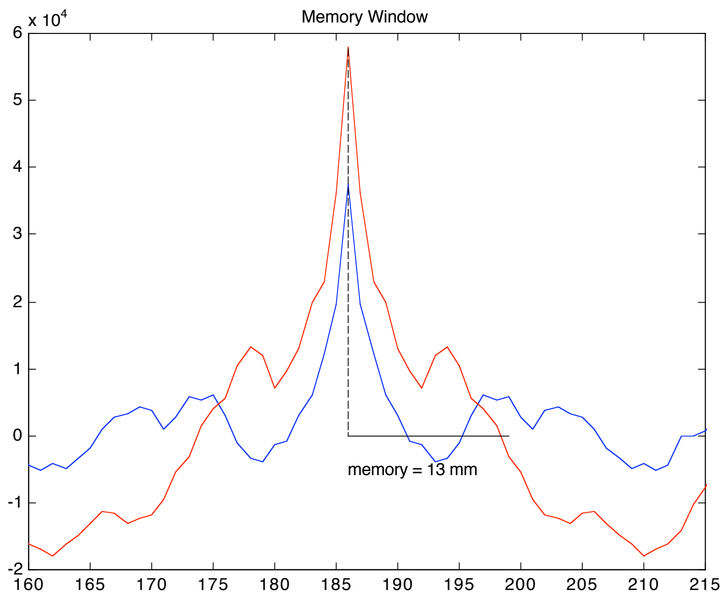


Figure 8 The memory window

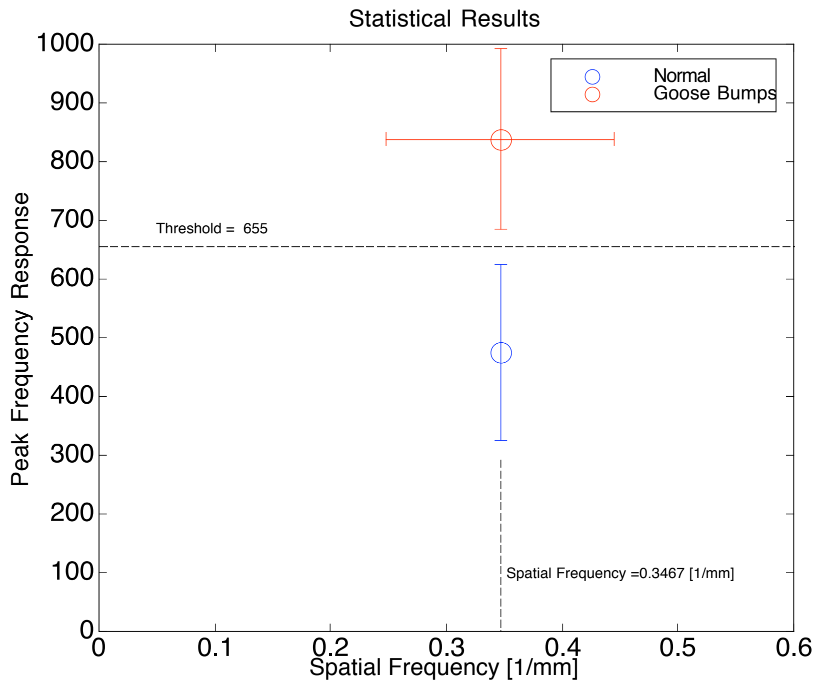
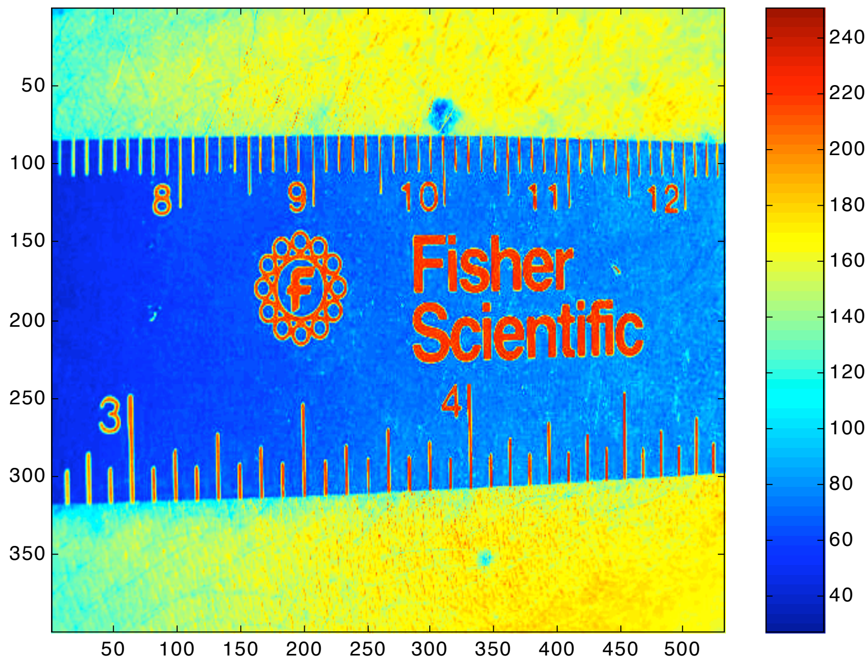


Figure 9 The mean and standard deviation of the maximum goose bump frequency component and the corresponding control value at that frequency.

Figure 10 The result from figure 9 shows that the spatial frequency of goose bumps is 0.3467 [mm^{-1}], so the goose bump spacing should be

about 2.88 [mm]. As a check, 2.88 mm lines are drawn in black. It can be seen that they are about equal to the goose bump spacing.

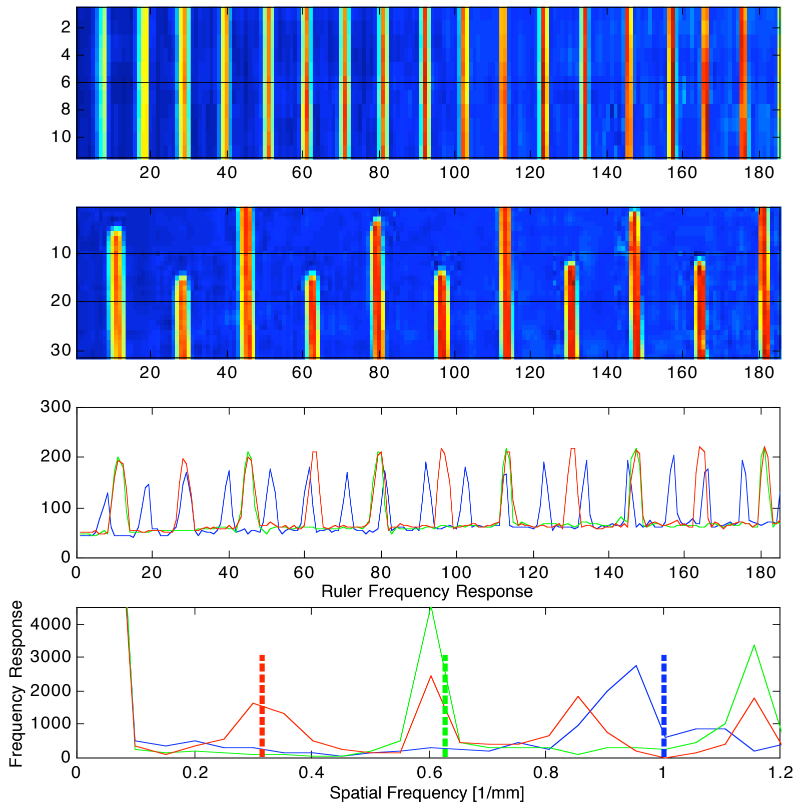
APPENDIX



The scale image of a ruler

The picture is 532 pixels wide which corresponds to 54 mm. The conversion factor from pixels to mm is then 54[mm]/532[pixels]

As a check, samples were taken along the tick marks:



By taking the fft of the pixel samples, and dividing the fft index by the product of the sample length and the sample spacing calculated above, the frequency components are plotted as solid lines in terms of true spatial frequency. The dashed lines represent where we expect to see the first peak frequency component based on the reciprocal of the tick-mark spacing on the ruler.