TEXTURE SENSING AT A FINGERTIP

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ABSTRACT
A new method for texture sensing, based on a calculation of the average standard deviation of the data from a thick film piezoelectric sensor, is presented. The repeating patterns in the surface texture of gratings as they move past the sensor are observable in the output signal. A comparison with a previous method has shown an improvement in the variability of the analyzed data. The method applied is not only able to distinguish two patterns of gratings, but also provides the dimension of each grating. The results have demonstrated the suitability of this approach as a fingertip texture sensor.

KEY WORDS
Prosthetic; texture; artificial hand; pzt

1. Introduction
Tactile sensing is a very important survival tool in human everyday life. One of its tasks is for texture exploration. A study shows that humans are able to discriminate two gratings that have spatial period difference of the order of 45µm [1].

Worldwide, prosthetic hands have been designed to regain the appearance and performance of a natural hand for hand amputees [2]. Artificial hands require automatic holding of objects using feedback control. To achieve this aim, they require sensors which should be capable of detecting the relative movement between the surface of a grasped object and the hand as well as to detect the surface condition of the object.

Research has been carried out to discriminate between different textures. Fourier coefficient analysis has been used to distinguish several textures by using Polyvinylidene Fluoride (PVDF) films embedded in silicone [3]. The sensor outputs had different frequency response for different textures. Others have demonstrated that the signals produced by the sensors are significantly different for different materials and hence should be able to distinguish between different surface textures [4][5].

The fundamental principle of detecting tactile information is based on analyzing the output signal pattern from the sensors [6]. In a previous paper, the authors have made calculations of the standard deviation of the sensor signals that provide information about surface texture [7]. This paper describes and discusses a second method (method 2), also based on the calculation of the standard deviation of the data.

2. Experiments
A purpose built experimental apparatus has been designed to move a hollow aluminium tube past a fingertip at a constant velocity (Figure 1). Attached to the fingertip is a piece of cosmetic glove material made of silicone. A lead zirconate titanate sensor has been fabricated onto the fingertip (Figure 2) [8]. A charge amplifier is used to extract data from the fingertip sensor.

Figure 1. Photograph of the experiment together with the main devices.

Figure 2. The fingertip with a piezoelectric sensor fabricated on it.

Figure 3 shows a cross-sectional view of the sliding block and the fingertip. The two arrows show the direction of movement of the sliding block which is perpendicular to the PZT sensor on the static fingertip.
3. Results

Two output signals of the sensor, using the coarse grating and fine grating, have cyclic variations as shown in Figure 5(a) and 5(b).

3.1 Results: Cross-sectional view illustration of the fingertip sensor and the block when sliding takes action.

On the surface of the block, there are coarse and fine gratings which are made from Perspex. Figure 4(a) & 4(b) show the magnified side view of the two gratings respectively. The coarse grating has a repeating pattern of grooves every 0.469mm. The widths of the grooves are 0.175mm. Similarly, the fine grating has repeats of grooves (width 0.172mm) every 0.258mm.

4. Analysis

The same number of data points (7 525) are used every time the standard deviation is calculated in the second method (Figure 7). In order to use all the data, for every window length calculated, the window number varies.

Defining \( W \), as the number of data points in a window and \( D \) as the total number of data points used, the number of windows, \( M \) is \( D / W \).

The index for the number of windows, \( m = 1, 2, ... M \)

The data, \( D = \{ d_1, d_2, ... d_n \} \)

The window length index, \( x = 1, 2, 3, ... W \)

\[ SD_x = SD (d(1+(m-1)W)) \]

For example, when \( x = 1 \),

\[ SD_1 = SD (d(1+(1-1)W)), d(1+(2-1)W), d(1+(3-1)W), ... , d(1+(M-1)W)) \]

\[ SD_{cycle} = average (SD_1, SD_2, ..., SD_W) \]
The difference between the method described in this paper (method 2) and that in a previous paper (method 1) is the number of data points used in the calculations of the average standard deviation. In method 1, the number of data values used depends on the window length which is constant. For small sizes of windows, less data is used in method 1 [7].

Figure 8(a) and 8(b) show the results of method 1 and method 2 analysis of the coarse grating from fingertip data respectively. In these figures, there are repeating notches in the values (at 99, 198 and 297). These features correspond to the detection of the grating moving past the fingertip. Figure 9(a) and 9(b) show the results of method 1 and method 2 analysis of the fine grating. There are repeating notches at the values of 128, 256 and 384.

Further experiments have shown that the repeats in the standard deviation occur at a lower or higher rate depending on the set velocity in proportion to the measured velocity obtained from the encoder connected to the motor that drives the grating over the fingertip.

5. Discussion

There is less variability in the standard deviation data for method 2 compared to method 1 [3]. The reason for this improvement is that more data is used in method 2 especially in the lower numbers of standard deviation data points.

At the window length corresponding to the grating period, (at point 99 in Figure 8(b)) the drop in standard deviation is about thirteen percent.
Using method 1, the drop is greater at about twenty three percent. However, method 2 is preferable as the standard deviation before the drop is very steady compared to more varied values found in method 1. A further consideration is that method 1 is a faster algorithm since it uses less data.

A similar observation can be seen with the fine grating, except that the notches are not as distinct. There is a fall of about three percent for the second method compared to fifteen percent in the first method.

The separation between the first and second notches is exactly the same as the separation between the second and third notches. All three notches are separated by exactly ninety nine points for the coarse grating. Similarly, the fine grating has repeats at every one hundred and twelve data points. The second and third notches occur because of the repeating cycle of the output signals.

6. Conclusion

For the method described in this paper, there is less variability in the average standard deviation compared to the first method. This lower variability is an advantage over the first method but more calculations are required. When the window size is the same as that corresponding to the period of a grating, the average standard deviation reaches a minimum value.

References