Characterization of Test Balls for Psychophysical Experiments

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Abstract

This report documents shape and curvature measurements of seven test spheres and three control spheres used in psychophysical experiments in the Biorobotics Lab.

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1 Introduction

It is of interest to determine how well humans can detect distortions of spherical objects and to discover the stereotyped movements, coined “Exploratory Procedures” by Lederman and Klatzky, which they use to make such discriminations. In order to conduct experiments in this area, a supply of spheres must be available with precisely specified distortions, as well as control spheres which are considered perfectly round. The control spheres can be easily purchased from a variety of sources. For example, our initial studies use 0.4996 inch diameter ball bearings made of highly polished, hardened steel. If a subject is to detect deviations from perfect sphericity, they may use a variety of cues, depending on how the reference spheres are distorted. These cues may include

- Eccentricity.
- Texture.
- Local Curvature.

We wish also to distort these spheres in precisely defined ways, ideally to determine a sensory threshold for a specific attribute. However, not all of these cues are variable independently. Since a sphere is defined as a surface of constant local curvature, any amount of eccentricity would also change local curvature.

There are many other possible distortions of a sphere which might lead to interesting haptics research, however more straightforward results will be obtained if we can set just one of the above three variables as an independent one, and minimize variations on the other two.

This report documents the measured shapes of seven distorted and polished balls used in psychophysical experimentation to assess human ability to perceive distortions from sphericity. Details of the metalworking processes, polishing methods, and measurement methods are available in other reports[1, 2].

2 Measurements

Measurement procedures, calibration, and data analysis are described in Hannaford and Dosher [2].

2.1 Polished Control Ball

Three sets of measurements taken every 10 degrees around a tumbler-polished control ball were acquired and processed. The results are given in Figure 1.

The minimum and maximum curvature was 3.2 and 5.0 inches$^{-1}$ respectively.
Figure 1: Analysis of data from three measurements of a tumbler-polished control ball. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.

2.2 Measurements of test balls

(see next page)
Figure 2: Test Ball 733. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.
Figure 3: Test Ball 814. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.
Figure 4: Test Ball 498. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.
Figure 5: Test Ball 784. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.
Figure 6: Test Ball 155. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.
Figure 7: Test Ball 532. Measurements shown with open circles. Interpolation plotted as solid line. (L to R): Sphere profile, first two derivatives plotted on the circle, calculated curvature.
<table>
<thead>
<tr>
<th>Ball</th>
<th>Min Diameter</th>
<th>Min Curvature</th>
<th>Max Curvature</th>
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</thead>
<tbody>
<tr>
<td>733</td>
<td>0.4770</td>
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<td>6.13</td>
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<td>1.97</td>
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<td>2.86</td>
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<td>4.67</td>
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<td>polished ctl</td>
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<td>2.88</td>
<td>4.94</td>
</tr>
</tbody>
</table>

Table 1: Curvature extrema computed from three measurements of each sphere.

2.3 Min and Max Curvature

The scilab script was modified to compute minimum and maximum curvature for each ball by taking the average of the min and max values for each of the three curvature measurements. The results are plotted in Table 1.

The scilab code added for estimating the extrema was:

```plaintext
Get max and min curvature

minc = 99999;
maxc = -99999;

for(t=1:dtd:360) do
    if(K(t) < minc) minc = K(t); end;
    if(K(t) > maxc) maxc = K(t); end;
end;

cmax = cmax + maxc; // accumulate averages

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```
References
