A Consideration of Inflatable Circles

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1 Introduction

This is a study of the basic math of inflatable spheres as a tool for soft robotics. We begin with a study in two dimension to simplify the problem. Our final goal is to analyze three dimensional soft robots composed of inflatable spheres.

2 Problem I: Circles in Fixed Postions

A very simplified version of the problem is to imagine that a two-dimensional plane. Instead of spheres, we will assume we have circles of changable radius. This is in fact realistic of a soft robot constrained to a plane.

Eventually we hope to have circles pressing against each other, or tangent or "kissing". However, the problem is a bit simpler if we assume we have two circles, each of which is constrained to have its center on the a vertical line (see Figure 1.) We place the circle C_1 with radius r_1 on the $x = -1$ line, and assume that it rests on a shelf or plane on the x-axis. Assume the C_2 circle whose radius if r_2 is on the $x = 1$ line.

Let A the intersection of the tangent line supported by the inflatable circles with the x-axis. Call the distance of A on the x-axis x. Let ψ be the angle formed by the circle centers with the x axis (measured counterclockwise).

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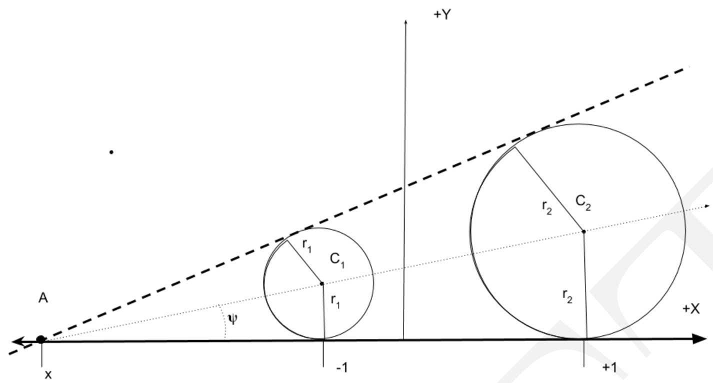

Figure 1: Problem I: Fixed Circles Centers

$$\tan\psi = \frac{r_1}{x-1} = \frac{r_2}{x+1} \tag{1}$$
$$r_2(x-1) = r_1(x+1) \tag{2}$$
$$r_2x - r_2 = r_1x + r_1 \tag{3}$$
$$r_2x - r_1x = r_1 + r_2 \tag{4}$$
$$x(r_2 - r_1) = r_1 + r_2 \tag{5}$$
$$x = \frac{r_1 + r_2}{r_2 - r_1} \tag{6}$$
$$\tan 2\psi = \frac{y}{x} \tag{7}$$
$$2\psi = \arctan \frac{r_1}{\frac{r_1+r_2}{r_2-r_1} - 1} \tag{8}$$
$$\psi = \frac{\arctan \frac{r_1}{\frac{r_1+r_2}{r_2-r_1} - 1}}{2} \tag{9}$$
$$\tag{10}$$

3 Problem II: Tangent Circles