Consider the following system. In an interval of length L with boundary, there sit n balls of radius R with uniform mass m. Their distances along the x-axis are denoted by x_i. We assume elastic collisions between the balls and their neighbors and with the boundary. We define the repulsive force of x_i on x_j to be proportional to the overlap of the balls given by

$$f_{ij}(2R - |x_j - x_i|) = \begin{cases} 2R - |x_j - x_i|, & \text{if } 2R > |x_j - x_i| \\ 0, & \text{if } 2R \leq |x_j - x_i|. \end{cases}$$

Note that this can be written as $f(x) = x\text{unitstep}[x]$, where unitstep$[x]$ is a step function which is equal to 0 for negative values and equal to 1 for positive values. So we have a Hooke-esque law relating the force, F, to the overlap, f: $F_{ij} = Ef_{ij}$, where E is a constant of elasticity. This system is governed by Newton's second law of motion: $\sum F_{ij} = m\ddot{x}_i$. We now have a system of second-order differential equations

$$\begin{cases} \ddot{x}_1 = (R - x_1) \text{ unitstep}[R - x_1] + \frac{E}{m} \sum\limits_{j=1}^{n} (2R - |x_j - x_i|) \text{ unitstep}[2R - |xj - xi|] \text{ sign}[x_j - x_i] \\ \ddot{x}_i = \frac{E}{m} \sum\limits_{j=1}^{n} (2R - |x_j - x_i|) \text{ unitstep}[2R - |x_j - x_i|] \text{ sign}[x_j - x_i] \\ \ddot{x}_n = (L - R - x_n) \text{ unitstep}[(L - R - x_n)] + \\ \qquad \frac{E}{m} \sum\limits_{j=1}^{n} (2R - |x_j - x_i|) \text{ unitstep}[2R - |xj - xi|] \text{ sign}[x_j - x_i]. \end{cases}$$

In theory, solving this system will give us positions of each ball before the next collision. In practice, this is nearly impossible to do analytically. We treat this as a difference equation and let mathematica do the heavy lifting. The output is a nice simulation with a plot of the distribution of all pair-wise distances.