

Introduction

The butterfly effect states that small changes in the initial conditions of a deterministic system can lead to large effects in later stages. This sensitive dependence on initial conditions can be seen when a ball is dropped through a Plinko Board for a large number of trials. Sixty videos were taken of a ball dropped into a Plinko Board with nearly the same initial conditions in order to observe chaos theory's butterfly effect in action.

Phantom v9.1 High Speed Camera

3 GB of RAM

576 x 768 pixels

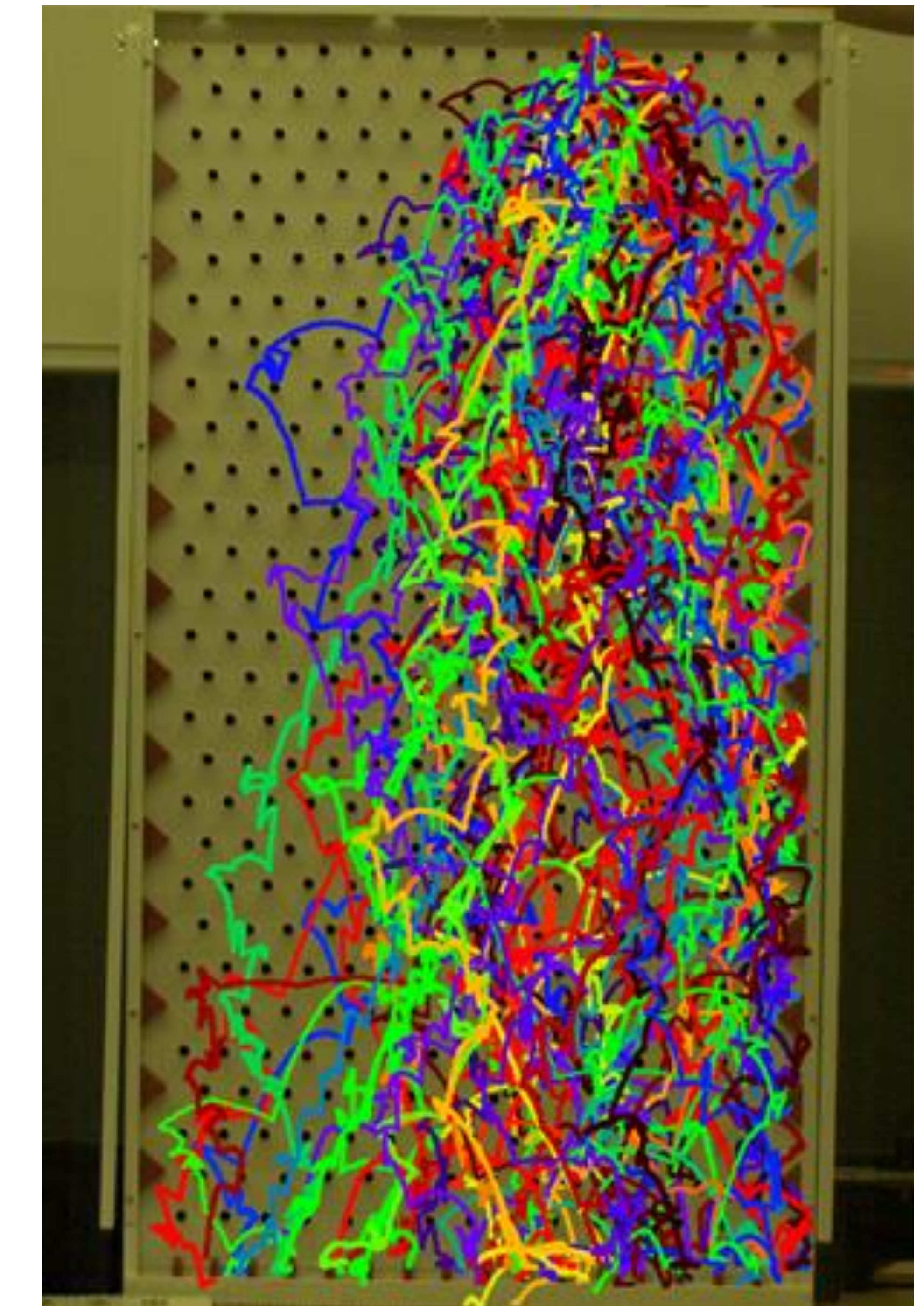
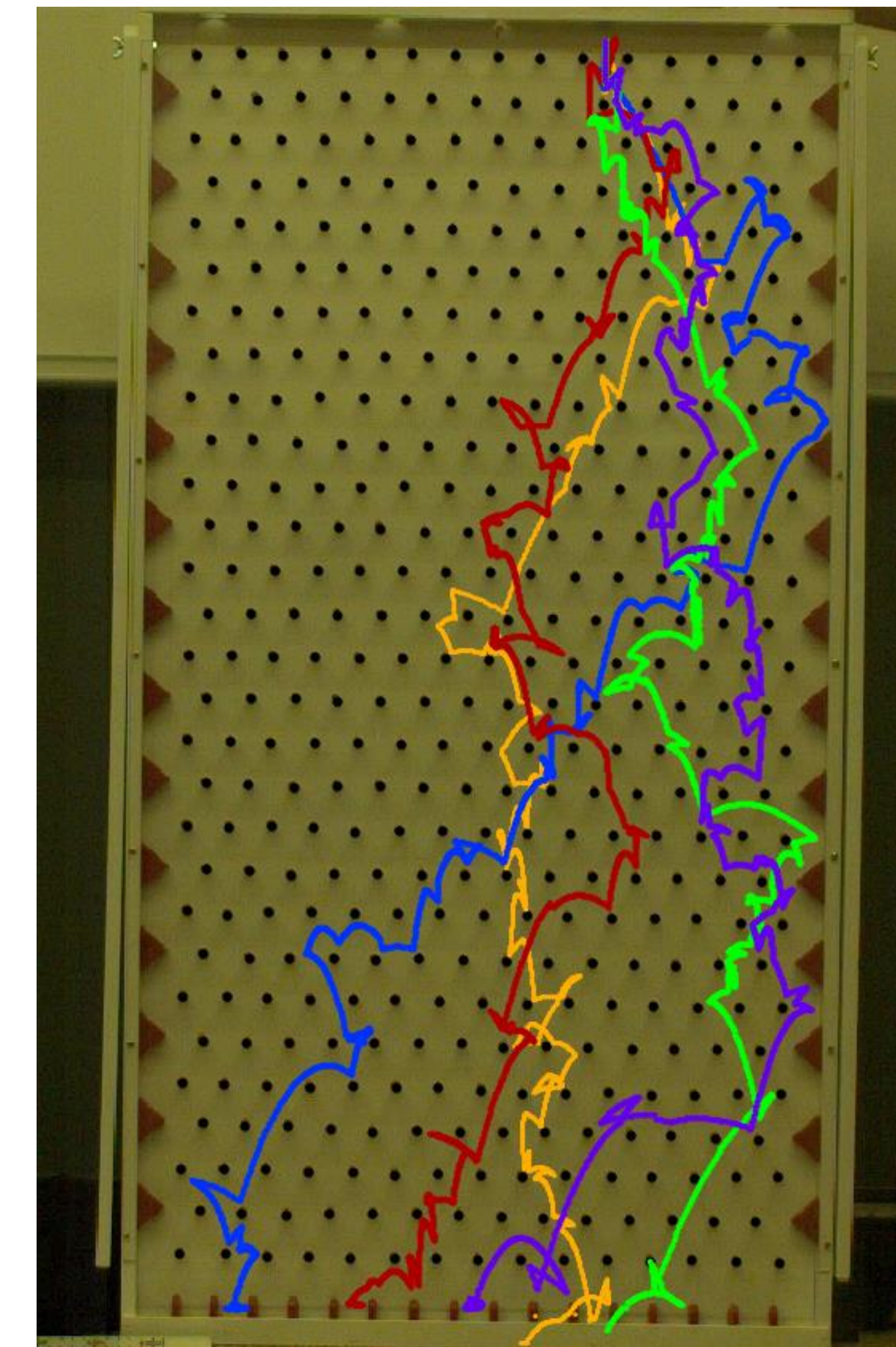
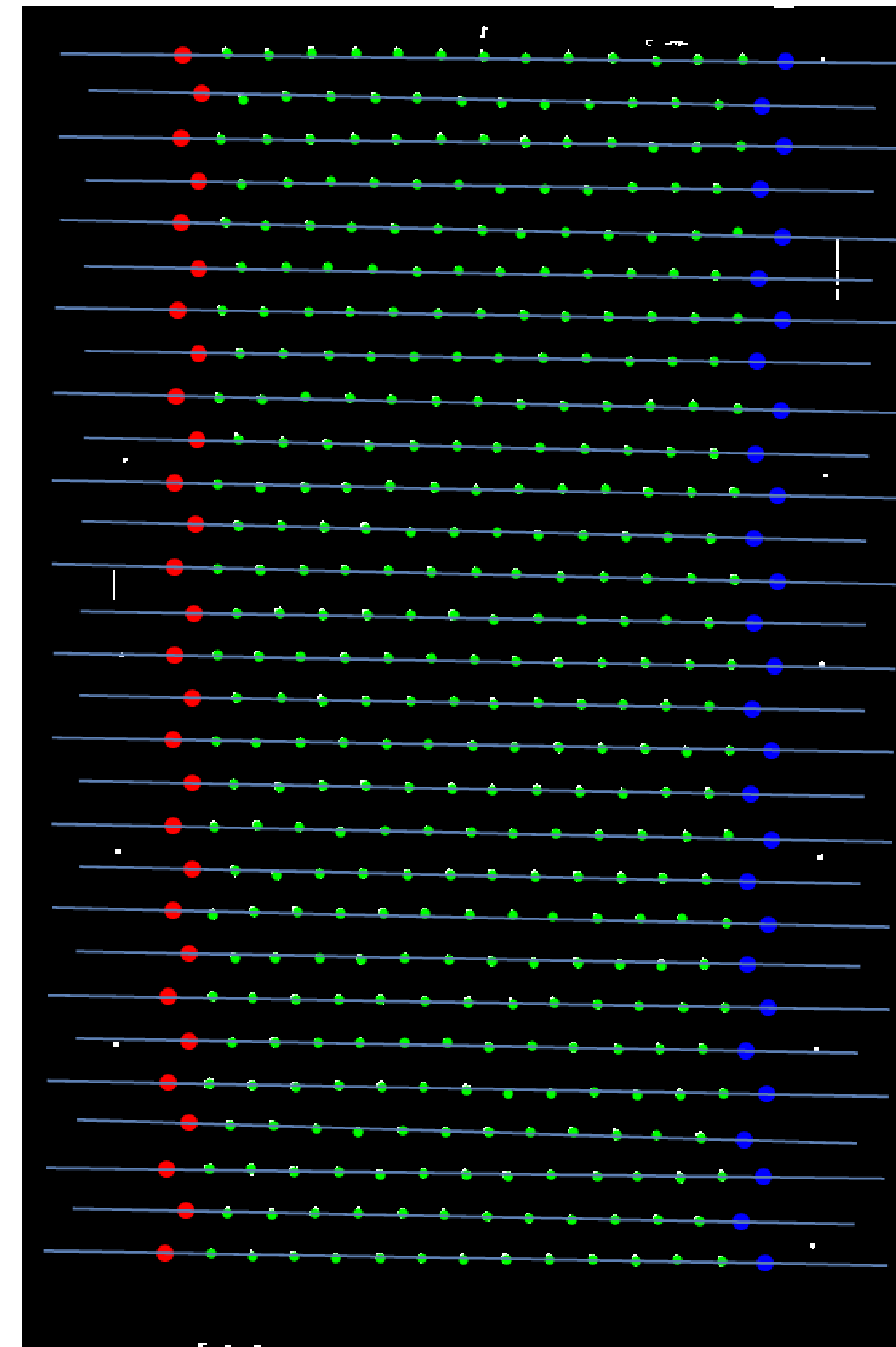
500 fps

9 seconds



Image Analysis

TEMA tracking software was used to track the position of the ball through each video. Manipulating the image of the empty Plinko Board to be black and white allows the computer to find individual pegs easily. The pegs along the left and right boundaries were found to find the equations of the lines representing one gate level. Using *Mathematica*, the tracking information and the manipulated image of the Plinko Board were combined to plot a single ball path, any subset of paths, and eventually all sixty paths.



Statistical Analysis

The elapsed time for each ball to get through a gate level was calculated in *Mathematica*. Figure 1 shows the elapsed time to reach each gate level. Boxplots display visually the distribution of all sixty trials, including the minimum, median, and maximum elapsed times.

In all sixty trials, the ball went through a right gate 47.7% of the time and through a left gate 52.3% of the time relative to the previous gate. Because the percentages are both nearly 50%, the gate entered relative to the previous gate is a nearly random event.

The histograms in Figure 2 show the percentage of balls that fell through each individual gate on a given level. In the second gate level, there is little scatter across the gates. The further down the Plinko Board, the distribution spreads out. By showing that small differences in initial conditions lead to big changes, the Plinko Board experiments demonstrate the butterfly effect.

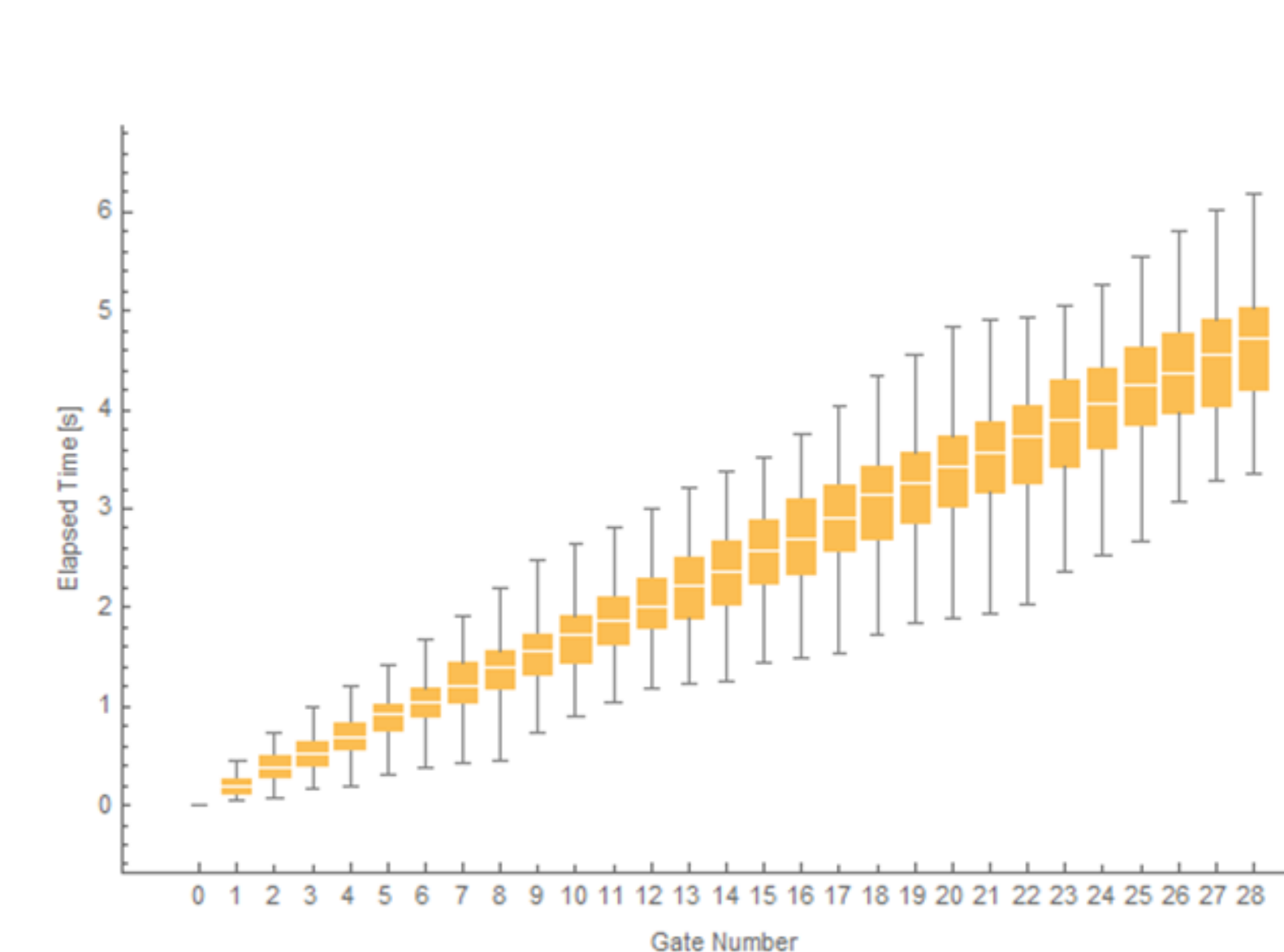


FIGURE 1

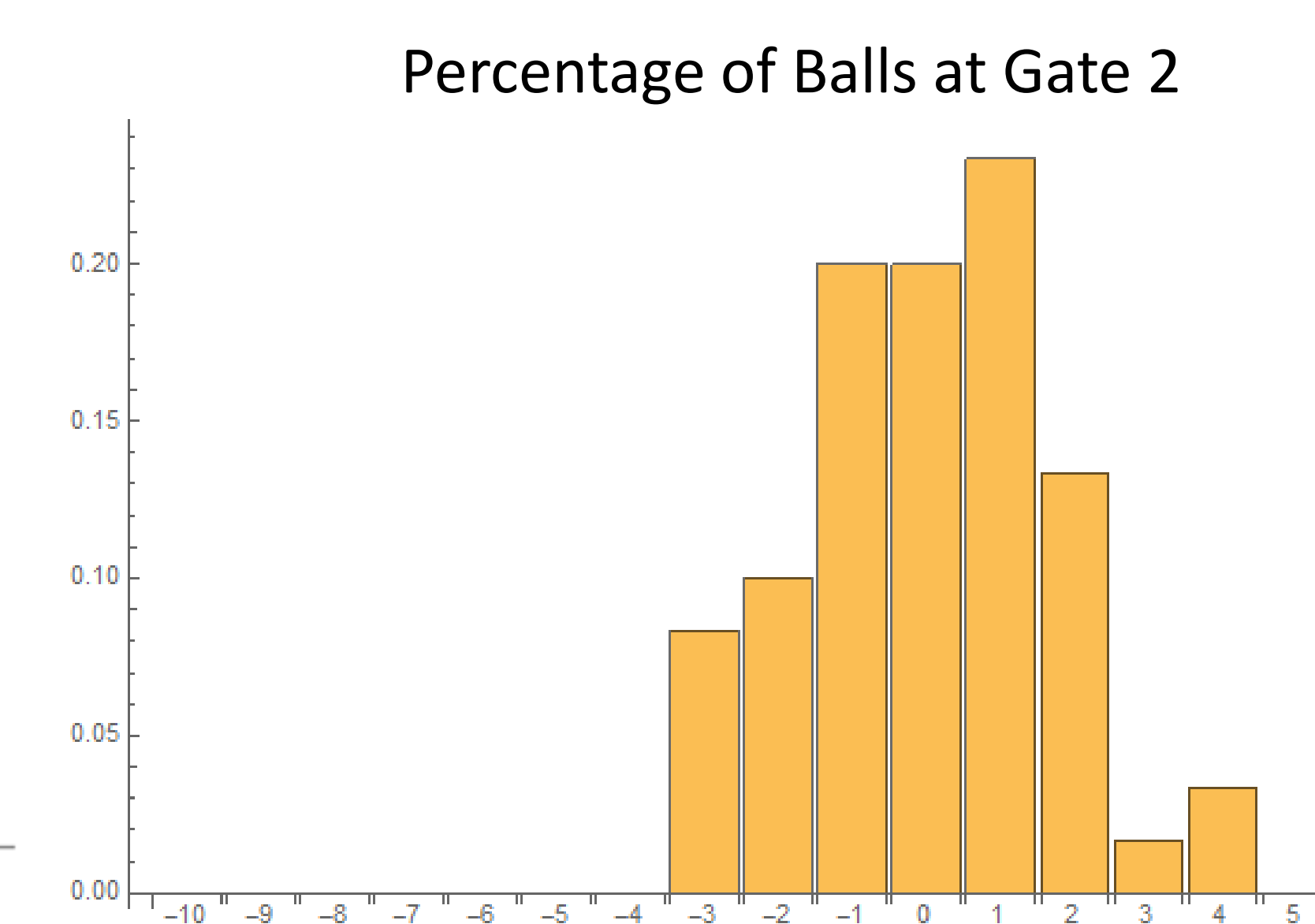


FIGURE 2a

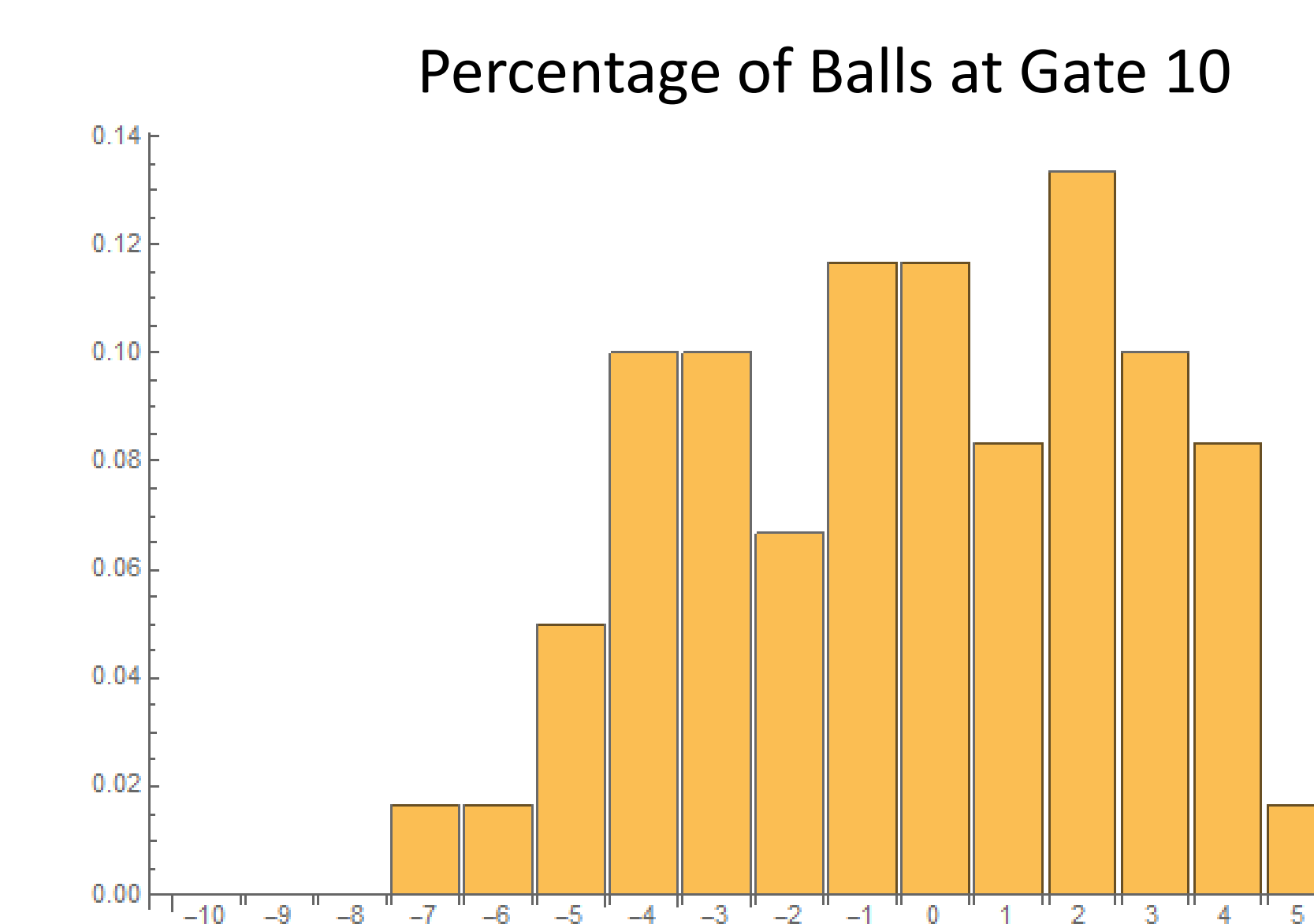


FIGURE 2b

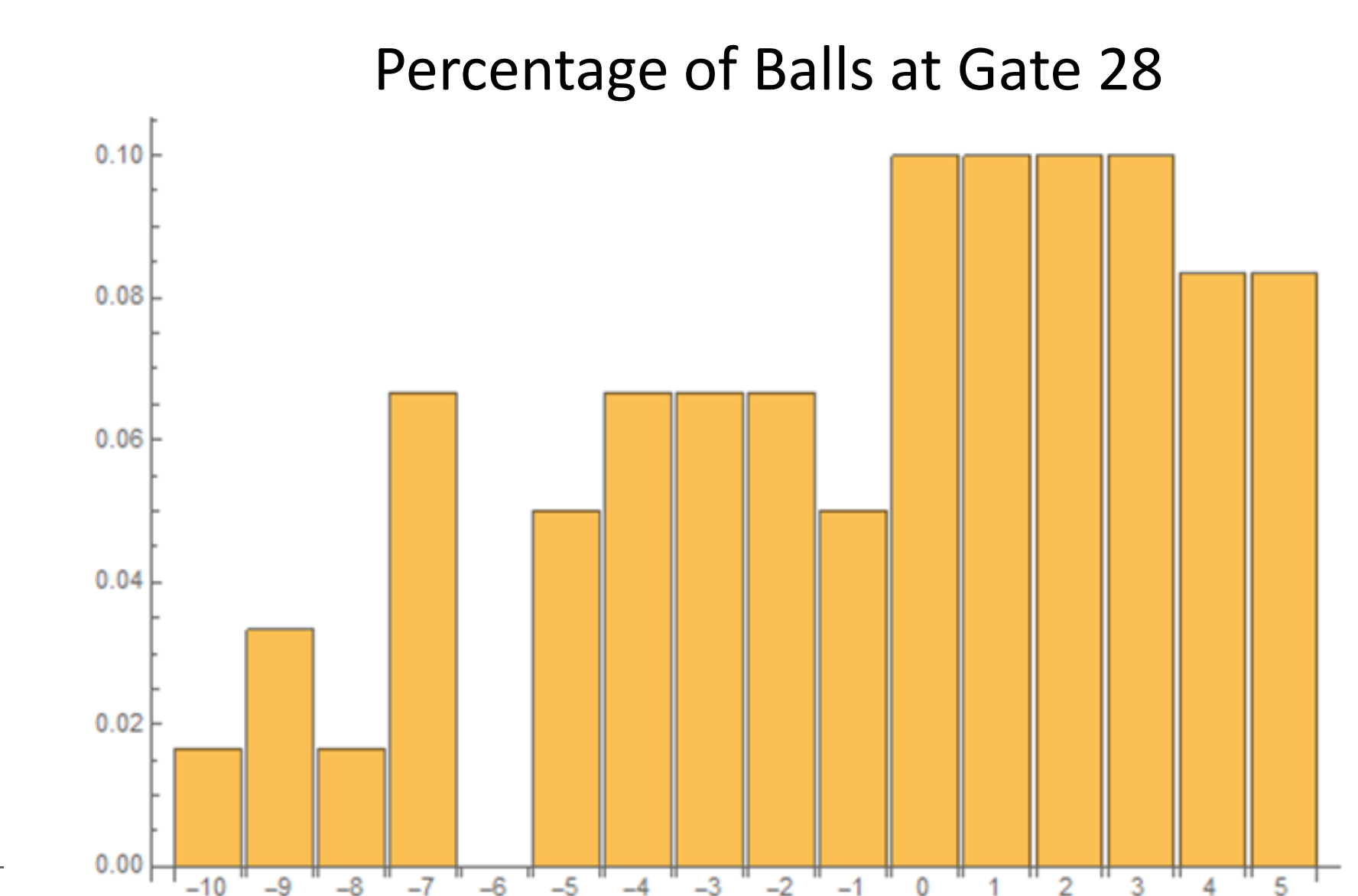


FIGURE 2c