The Mathematics of Gambling

Physical Prediction of Roulette II

by Edward O. Thorp

I found with further experiments that my half-sized wheel was really very irregular. The track was curved like a tube and the ball "rattled around" erratically, up and down, as it orbited. The slick bakelite surface was moulded, not machined. It also skidded and bounced. And there was a horizontal junction which added irregularities to the track.

But full sized wheels were not like that. In December, 1958, I made my first visit to the casinos. I observed several regulation wheels and found that the ball moved smoothly in its track. Also the track was a pair of flat beveled, carefully machined surfaces, not a tube. When I saw how good the casino wheels were, I was more convinced than ever that prediction was possible. But I needed a full-sized wheel and some good laboratory equipment to continue. How could I pay for it? I got my Ph.D. in June of 1958 and was teaching at UCLA. Though my wife was finally able to stop working, we had no savings and I barely supported us. I couldn't ask her to go back to work to buy me a roulette wheel and to finance my pipe dream.

But I persisted. I simulated the study of the problem of whether the roulette ball would, for the same starting velocity, travel about the same distance along the track. I set up a little vee-shaped inclined trough. I would start a marble from a fixed height (a mark on the trough) and measure how far across the floor it rolled. I was encouraged but not surprised to find that the distance the marble went could be predicted closely from the starting height.

One memorable evening when my in-laws were due for dinner, I ran overtime on a marble experiment. They came into the kitchen wondering why I hadn't come to greet them at the door. They found me rolling marbles down a little wooden trough and across the floor. All over the floor were little distance markers and pieces of tape.

In early 1959 Vivian and I spent time with Mel and Judy Rosenfeld, working on a radio link for the casino test of my yet to be completed roulette system. We took model airplane radio control equipment and altered it somewhat. We succeeded in getting a workable but somewhat inconvenient radio link.

Then around March or April of 1959, I pushed the roulette project aside. Twelve man years of blackjack calculations arrived, courtesy of Baldwin, Cantey, Maisel and McDermott. I had convinced myself (as described in "Beat the Dealer") that I could devise a winning blackjack card counting system and now I set to work on this intensely. The impractical marble roller now said he could beat the casinos at blackjack. What next?

I wrote my blackjack computer programs in the summer and fall of 1959. Testing and debugging followed, and then from late 1959 through early 1960 my computer production runs produced the basic results that gave me the five-count system in early 1960. Then during 1960 I worked out most of the ten-count system and the ideas for the ultimate strategy. I also made the computer runs and worked out the methodology so that all of today's so-called "one parameter" blackjack systems could be readily devised by anyone versed in the use of computers. In December 1960, The Notices of the American Mathematical Society carried the abstract of my upcoming talk, "Fortune's Formula: The Game of Blackjack." Life would never be the same again. The intense professional and public interest aroused by the abstract, even before the talk, led me to seek quick publication in a scientific journal. I chose to try the Proceedings of the National Academy of Sciences. I needed a member of the Academy to communicate (i.e. approve and forward for recommended publication), so I sought out the one mathematics member of the Academy at M.I.T., Claude Shannon.

My Original Plan Was to Divide the Motions of the Ball into Parts and Analyze Each One Separately

Claude Shannon: Genius

Shannon, then in his early forties, was and is one of the most famous applied mathematicians in the world. As one genius among many, he was relatively unnoticed as a graduate student—until he handed in his master's thesis. It developed the mathematical theory of switching electrical networks (e.g. telephone exchanges) and became the landmark paper in the subject. After receiving his doctorate, Shannon worked at Bell labs for several years and then became world-famous for papers establishing the mathematical foundations of information theory.

I was able to arrange a short appointment early one chilly December afternoon. But the secretary warned me that Shannon was only going to be in for a few minutes, not to expect more, and that he didn't spend time on subjects (or people) that didn't interest him (enlightened self-interest, I thought to myself).

Feeling both awed and lucky, I arrived at the Shannon's office for my appointment. He was a thinnish alert man of middle height and build, somewhat sharp featured. His eyes had a genial crinkle and the brows suggested his puckish incisive humor. I told the blackjack story briefly and showed him my paper. We changed the title from "A Winning Strategy for Blackjack" to "A Favorable Strategy for Twenty-One" (more sedate and respectable). I reluctantly accepted some suggestions for condensation, and we agreed that I'd send him the retyped revision right away for forwarding to the Academy.

Shannon was impressed with both my blackjack results and my method and cross-examined me in detail, both to understand and to find possible flaws. After my few minutes were up, he pointed out in closing that I appeared to have made the big theoretical breakthrough on the subject and that what remained to be discovered would be more in the way of details and elaboration. And then he asked, "Are you working on anything else in the gambling area?"

I decided to spill my other big secret and told him about roulette. Several exciting hours later, as the wintery sky turned dusky, we finally broke off with plans to meet again on the roulette project. Shannon lived in a huge old three story wooden house on one of the Mystic Lakes, several miles from Cambridge. His basement was a gadgeteer's paradise. It had perhaps a hundred thousand dollars worth of electronic, electrical and mechanical items. There were hundreds of categories, like motors, transistors, switches, pulleys, tools, condensors, transformers, and on and on.

Our work continued there. We ordered a regulation roulette wheel from Reno and assembled other equipment including (most important) a strobe light and a large clock with a second hand that made one revolution in one second. The dial was divided into hundredths of a second and still finer time divisions could be estimated closely. We set up shop in "the bil-

Continued on next page

liard room," where a massive old dusty slate billiard table made a perfect solid stable mounting for the roulette wheel.

Analyzing the Motion

My original plan was to divide the various motions of ball and rotor into parts and analyze each one separately. They were:

- The ball is launched by the croupier. It orbits on a horizontal track on the stator until it slows down enough to fall off this (sloped) track towards the center (rotor). Assume at first that (a) the wheel is perfectly level, and (b), the velocity of the ball depends on how many revolutions it has left before falling off. Referring to figure 2 of the May, 1979 article, (b) means that every spin would produce the same curve, not different ones like my half-sized wheel. Put another way, this means that if you timed one revolution of the ball on the stator, you could tell how many more revolutions and how much more time until the ball left the track. If these assumptions turned out to be poor, we would attempt to modify the analysis.

- Next analyze the portion of the ball orbit from the time the ball leaves the track until it crosses from the stator to the rotor. If the wheel is perfectly level and there are no obstacles, then it seems plausible that this would always take the same amount of time. (We later learned that wheels are often significantly tilted. This tilt, when it occurs, can affect the analysis substantially. We eventually learned how to use it to our advantage.) There are, however, vanes, obstacles, or deflectors on this portion of the wheel. The size, number, and arrangement vary from wheel to wheel.

On average, perhaps half the time these have a significant effect on the ball. Sometimes they knock it abruptly down into the rotor, tending to cause it to come to rest sooner. This is typical of "vertical" deflectors (ones approximately perpendicular to the ball's path). Other times they "stretch out" the ball's path, causing it to enter the rotor at a more grazing angle and to come to rest later, on average. This is typical of "horizontal" deflectors (ones approximately parallel to the ball's path).

- Assume the rotor is stationary (not real), and beat that situation first. Reasoning: if you can't beat a stationary rotor, you can't beat the more complex moving rotor. Here the uncertainty is due to the ball being "spattered" by the frets (the dividers between the numbered pockets). Sometimes a ball will hit a fret and bounce several pockets on, other times it will be knocked backwards. Or it may be stopped dead. Occasionally the ball will bounce out to the edge of the rotor and move most of a revolution there before falling back into the inner ring of pockets. Thus, even if we knew where the ball would enter the rotor, the "spattering" from the frets causes considerable uncertainty regarding where it finally stops. This tells you that there is no possible reliable "physical" method for predicting ahead of time which pocket the ball is going to land in, unless the wheel is grossly defective or crooked. That makes the roulette method "used" in the movie "The Honeymoon Machine" an impossibility. It also tells you that successful physical prediction can at most forecast with an advantage which sector of the wheel the ball will end in.

- Assume now that the rotor is moving. Generally the ball and rotor move in opposite directions, increasing the velocity of the ball relative to the rotor. We'll assume this is always the case. I've never seen or heard of a casino spinning ball and rotor in the same direction. If this were done, the relative motion of ball and rotor would be even less than with a stationary rotor and prediction would be easier yet. With a moving rotor, the amount of ball "spattering" is increased and predictability is further reduced. Note that this change depends on the rotor velocity. Since that varies from time to time and from croupier to croupier, this adds further complexity. It turns out that the velocity of the rotor changes very slowly, so it is possible to predict with high accuracy which part of the rotor will be "there" at the predicted time and place that the ball leaves the stator. **G**

(Continued next month)