On Predicting and Generating a Good Break Shot in Billiards Sports

Qianru Zhang*†, Zheng Wang*‡, Cheng Long§‡, Siu-Ming Yiu§†

1 New Billiards Datasets

1.1 Composition The dataset covers 227 players and 94 international professional 9-ball tournaments. We collect the billiard dataset for frames, turns and strikes.

In particular, (1) **Frame**: in each 9-ball game, there are a certain number of rounds (called frames). A frame starts with a break shot and ends when one player pockets the ball 9. (2) **Turn**: in each frame, the players take turns to pocket the balls with legal strikes and they switch turns when a player misses the ball or makes fouls. For example, if one player pockets all balls in a row without missing any balls or fouls after the break shot, there would be only one turn in this frame. (3) **Strike**: in each turn of a player, he/she performs strikes so as to pocket the object balls until he/she misses the balls or makes fouls. For example, the first strike in each frame corresponds to the break shot in the frame.

Data of Frames. Our dataset covers 3,019 frames and includes for each frame: (1) the break shot layout which consists of locations of the balls that remain on the pool table after the break shot and (2) three performance indicators. The first one is a binary tag indicating clear or not (where clear means that all objects are potted by the player who does the break shot, given the break shot layout and within the first turn and not clear means the other case). The second one is a binary tag indicating win or not (where win means that the player who does the break shot wins for the frame eventually and not win means the other case). The third one is the number of potted balls by the player who does the break shot, given the break shot layout and within the first turn.

Data of Turns. Our dataset covers 6,637 turns and includes for each turn: (1) the player name, (2) the number of strikes by the player, (3) the order of balls potted into pockets, (4) the type of the foul if any, and (5) data of the strikes that are within the turn as described below.

Data of Strikes. Our dataset covers 2,082 strikes and includes for each strike: (1) the trajectories of the cue ball and object balls that move as a result of the strike, (2) camera viewing angle, (3) the cushion on which the player hits the ball, (4) the intersection point between the stick and the cushion, (5) the position of the center of the cue ball, (6) the stick top position when the player hits the ball and (7) the direction (i.e., the angle between the stick and intersected cushion) in which the player hits the ball. Note that we have manually filtered out some strikes to guarantee a high quality of the trajectory data we collected, where the traces of balls cannot be accurately captured from the videos, which is mainly due to (1) some ball traces are blurred in the videos with the fast movements; (2) the object tracking of the balls is lost when the balls collide.

We also include detailed instructions of collecting our dataset and relevant documentation in the supplementary material so that they could be referred to for expanding the dataset as more tournaments are available in the future.

1.2 Collection Process The dataset is collected with the free software Kinovea, which can be downloaded via the link [1]. We collect data in following steps.

Step 1. Choosing a game, e.g., "James Aranas vs Thorsten Hohmann | 2019 US Open Pool Championship 2", where the number 2 denotes the Round-2 in this game, which is shown in Figure 1.

Step 2. Adding the "perspective grid" (calibrate 200*100) on the play field of the billiard table, and adding markers according to the following order: yellow, blue, red, purple, pink, green, brown, black, yellow stripes and cue ball (white), as shown in Figure 2. Note that if one ball was potted, add the marker outside the table for this ball, e.g., the marker for the pink ball is outside the table. The two buttons (i.e., "perspective grid" and "marker") are labelled with the red squares in Figure 2.

Step 3. We need to export to a spreadsheet as the MS-XML to record the coordinates, and keep the same name as the file. As shown in Figure 3, note that the Marker 1 for the yellow ball and the Marker 3 for the red ball are outside the pool table, and thus their coordinates on x-axis are the negative number with -6.04 and -5.21, respectively.

Step 4. Besides, we need to collect the aforemen-

* Equal contribution.
† The University of Hong Kong, {qrzhang, smyiu}@cs.hku.hk
‡ Nanyang Technological University, {wang_zheng, c.long}@ntu.edu.sg
§Corresponding author.

[1] https://www.kinovea.org/download.html

Figure 1: Adding the image of the break shot in Kinovea.

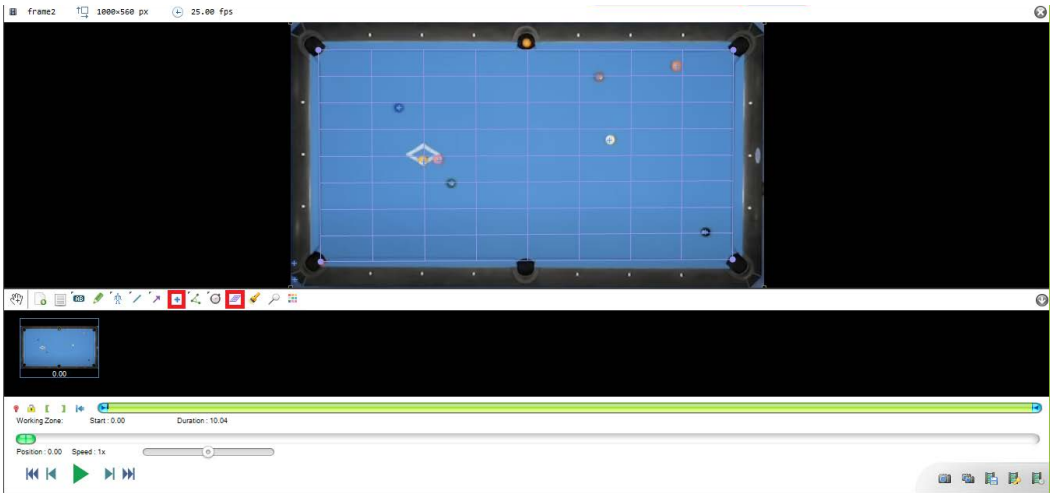
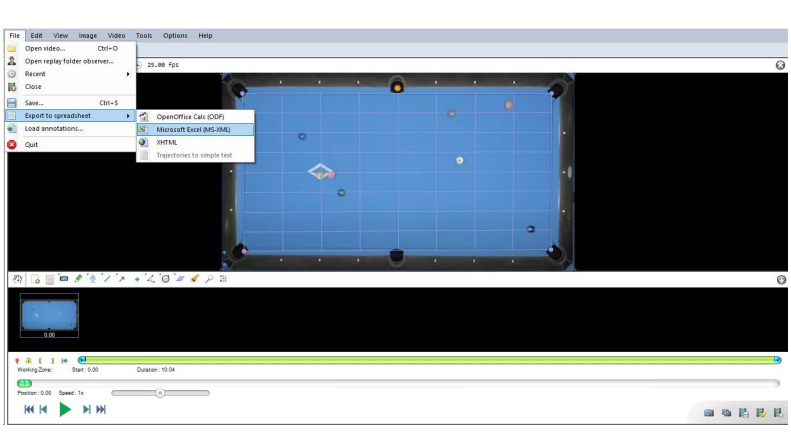


Figure 2: Adding the calibration and marker for the break shot in Kinovea.



Key Images	
Name	Time
0.00	0.00

Points			
Name	X	Y	Time
Marker 1	-6.04	84.94	0.00
Marker 2	41.74	72.27	0.00
Marker 3	-5.21	77.41	0.00
Marker 4	172.53	91.05	0.00
Marker 5	59.05	48.4	0.00
Marker 6	63.91	37.42	0.00
Marker 7	136.44	86.39	0.00
Marker 8	183.32	15.64	0.00
Marker 9	52.41	46.82	0.00
Marker 10	139.1	57.75	0.00

Figure 3: Export from the software Kinovea and exported XML file.

2019 US Open Pool Championship																
Finals - James Aranas vs Thorsten Hohmann			https://www.youtube.com/watch?v=jfiqP5Vk3Cw													
Frame	**Who BREAK**	**Potted when break**	**Potted after break**	**Clear**	**Win**	**Horizontal or Vertical**	**strikes of each turn**	**order**	**fouls**	**type of fouls**	**view**	**cushion**	**intersection distance**	**center of cue**	**stick top position**	**angle(°)**
1	Thorsten Hohmann	2	0	0	1	V	1	[]	0	N/A	V	3	5.43	14.29,144.30	13.65,153.46	83
	James Aranas						3	[2,4]	0	N/A	V	1	38.10	40.87,12.39	39.42,8.29	77
	Thorsten Hohmann						5	[5,6,7,8,9]	0	N/A	V	4	195.65	63.07,114.50	65.49,114.54	23
2	Thorsten Hohmann	2	0	0	1	V	1	[]	0	N/A	V	4	31.36	49.83,42.34	53.96,41.21	73
	James Aranas						1	[4]	0	N/A	V	3	53.64	64.26,176.01	62.23,182.11	71
	Thorsten Hohmann						6	[3,5,6,7,8,9]	0	N/A	H	4	18.75	20.75,28.65	19.93,19.67	84
3	Thorsten Hohmann	2	7	1	1	H	7	[2,3,4,5,6,8,9]	0	N/A	V	2	46.13	20.95,85.02	18.08,80.79	28
4	Thorsten Hohmann	2	7	1	1	V	7	[2,4,5,6,7,8,9]	0	N/A	V	3	48.50	42.06,132.01	42.92,132.01	83
5	Thorsten Hohmann	2	5	0	0	V	6	[1,2,3,5,6]	0	N/A	V	2	151.93	7.14,121.03	4.83,130.94	13
	James Aranas						2	[7,9]	0	N/A	V	1	74.71	45.98,71.77	49.08,63.96	68
6	James Aranas	1	8	1	1	H	8	[1,2,4,5,6,7,8,9]	0	N/A	V	1	66.39	72.01,85.98	70.95,73.50	86
7	James Aranas	0	0	0	0	V	1	[]	0	N/A	H	4	173.28	148.72,10.26	157.94,6.14	25
	Thorsten Hohmann						1	[]	0	N/A	V	1	44.58	52.57,14.73	50.62,11.69	59
	James Aranas						1	[]	0	N/A	H	1	92.70	8.10,92.10	4.31,92.10	85
	Thorsten Hohmann						9	[1,2,3,4,5,6,7,8,9]	0	N/A	V	2	22.88	37.67,13.89	33.45,13.97	78
8	Thorsten Hohmann	0	1	0	1	V	1	[]	0	N/A	V	4	180.62	87.18,145.75	90.95,151.26	17
	James Aranas						2	[1]	0	N/A	V	2	135.33	15.22,118.20	8.35,124.93	35
	Thorsten Hohmann						1	[]	0	N/A	V	2	189.18	23.23,176.19	17.90,174.28	57
	James Aranas						1	[]	0	N/A	V	1	72.99	65.04,57.26	66.02,49.85	81
	Thorsten Hohmann						8	[2,3,4,5,6,7,8,9]	0	N/A	V	2	182.87	22.68,176.20	19.09,172.24	55
9	Thorsten Hohmann	0	0	0	1	V	1	[]	0	N/A	V	2	188.90	13.56,148.25	9.26,157.85	28
	James Aranas						1	[]	0	N/A	V	1	42.17	40.74,78.76	41.35,69.31	88
	Thorsten Hohmann						3	[1,2]	0	N/A	V	1	27.42	32.03,20.16	30.28,16.07	81
	James Aranas						1	[]	0	N/A	V	3	90.25	86.45,168.79	87.15,178.89	83
	Thorsten Hohmann						1	[]	0	N/A	V	1	72.93	67.79,9.32	69.96,7.30	59
	James Aranas						4	[3,4,5]	0	N/A	V	3	87.22	81.19,170.90	83.32,178.97	79
	Thorsten Hohmann						4	[6,7,8,9]	0	N/A	H	4	107.16	102.63,6.36	105.21,2.74	56
10	Thorsten Hohmann	0	0	0	1	V	1	[]	0	N/A	V	4	186.99	87.18,145.74	90.08,155.02	19
	James Aranas						1	[]	0	N/A	V	1	64.76	64.14,94.21	64.76,85.64	89

Figure 4: Information included in the Variables.xlsx file.

tioned information from professional billiards games on YouTube. Figure 4 shows the information that is stored in the Variable.xlsx, where the label/meta information that is associated with each layout is also included, such as the player name, clear and win. In order to increase the usability of our dataset, we also collect for 2,082 strikes the corresponding trajectories of the cue ball and object balls that move as a result of the strikes. We provide the video link and the break shot images for each layout in the variable file to make sure the quality of the dataset, and we randomly choose some of games to double-check the accuracy.

Preprocessing. Locations of each billiards layouts are in the form of (x, y) such as $(139.96, 65.36)$. For the tasks of prediction and generation, we tokenize the locations with a predefined granularity (e.g., grid cell size 15). Besides, since the data is collected from the videos of billiard games, which are in one of the two angles, namely the horizontal viewing angle and vertical viewing angle, we preprocess the dataset consistently so that all layouts are converted to be in the horizontal viewing angle. We provide the preprocessing code via the link [2].

1.3 Documentation The dataset is stored in two parts, one part is trajectories, which includes 2,082 strikes of trajectories. Another part is 3,019 layouts which includes two folders, namely folder "Coordinates" and folder "Variables". (1) In folder "Coordinates", it includes some subfolders, and each subfolder stores a game with 1 to 25 XML files, representing layouts at different time points during the game. For example, in the subfolder named "2020 EUROTOUR-ITALIAN OPEN", file "Frame 1.xml" stores locations of balls that remain on the pool table after the break shot. (2) In folder "Variables", each subfolder also represents a game with a "variable.xlsx" file. The "Variable.xlsx" file stores some necessary information that is associated with each layout. Regarding the license, we use "CC0: Public Domain" for the dataset and "MIT license" for the code. We will release the dataset and the code once the paper is accepted.

Variables. The dataset includes the following variables that are associated with each billiards layout, whose the locations in the form of (x, y) to represent coordinates of the billiards balls that remain on the pool table after the break shot: (1) player names; (2) in which view, horizontal or vertical (according to the camera placed on the angle of the pool table, the locations of balls are collected in horizontal or vertical viewing angle); (3) in which order the balls are potted into the pockets; (4) the number of strikes each player made in his/her turn; (5) whether there are any foul behaviours in each turn; (6) what type of fouls in each turn; (7) in which cushion the player hits the cue ball; (8) the intersection point between the stick and cushion to the pocket; (9) the center position of the cue ball; (10) the top position of the stick; (11) the direction of the player hit the cue ball (i.e., the angle between the stick and intersected cushion); (12) clear labels (clear represents the player who performs the break shot potted ball 1 to ball 9 into pockets and win the game; not clear otherwise); (13) win labels (win represents the player who performs the break shot potted ball 9 into pockets; not win otherwise); (14) the number of potted balls after the break shot. We provide a real example to show the aforementioned

[2] https://drive.google.com/drive/folders/1NBqonYLr_cParMMn4xSeE0KTJNhjeYuG?usp=sharing

The collected billiards information			
1	Joshua Filler	8	$(0, 24.69)$
2	Horizontal	9	$(77.92, 14.03)$
3	(1,5),2,3,4,6,7,8,9	10	$(72.07, 14.94)$
4	7 (strikes in this turn)	11	$82°$
5	0	12	1 (clear)
6	N/A	13	1 (win)
7	the left side	14	7 (potted balls)

Figure 5: Left: a real break shot layout of the 2019 International 9-Ball Open by the player Joshua Filler in Frame 5, where the bottom left corner as origin $(0, 0)$ to record the coordinates of balls. Right: illustrating the collected information from 1 to 14 for the layout, and (1,5) in the third row of the table indicates the ball 1 and 5 are potted together by the break shot.

Table 1: Dataset statistics.

Dataset	#layouts	#strikes	#games	#players	year	x-axis	y-axis
Statistics	3,019	2,082	94	227	2000-2020	[0,200]	[0,100]

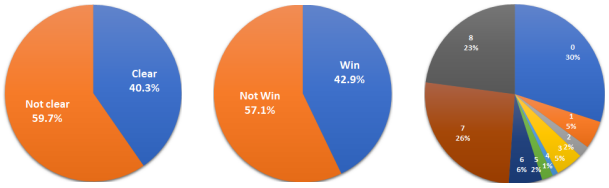


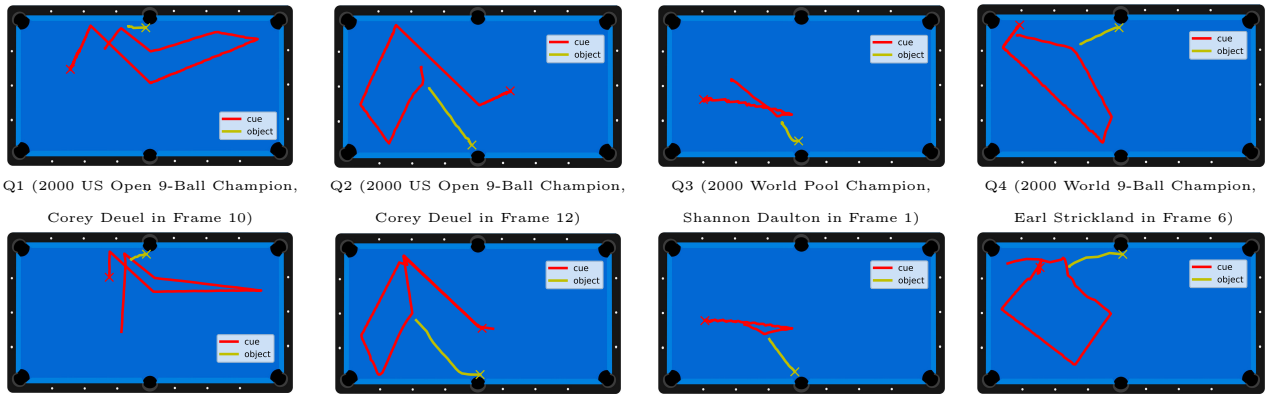
Figure 6: The distribution of clear, win and the number of potted balls.

information in Figure 5.

Statistics. In this part, we report the detailed dataset statistics in Table 1. We also report the distribution of clear labels, win labels and the number of balls potted after break shots in Figure 6.

2 Evaluation on the Similar Strike Retrieval

We study a light similar billiards strike retrieval task, which aims to retrieve the similar strikes from the dataset for a given query strike. In particular, we measure the similarity between two strikes by first comparing trajectories of the cue ball and the hit object ball and then aggregating the similarities between the two trajectories as one between the two strikes. To measure the trajectory similarity, we adopt the DTW since it captures the shape information of the billiards trajectory well and is widely adopted. In Figure 7, we report the Top-1 results of similar strike retrieval task on four randomly selected query strikes. For each strike, we provide the source of the strike and the player who performs the strike. We observe the Top-1 result matches the query very well, and the quality of the collected trajectory data has also been verified to support some applications.



Q1 (2000 US Open 9-Ball Champion, Corey Deuel in Frame 10)

Q2 (2000 US Open 9-Ball Champion, Corey Deuel in Frame 12)

Q3 (2000 World Pool Champion, Shannon Daulton in Frame 1)

Q4 (2000 World 9-Ball Champion, Earl Strickland in Frame 6)

R1 (2019 International 9-Ball Open, Darren Appleton in Frame 19)

R2 (2019 International 9-Ball Open, KO Pin Yi in Frame 12)

R3 (2019 World 9-Ball China Open, Ruslan Chinakhov in Frame 5)

R4 (2019 CBSA Miyun 9-Ball IC, Chang Yu lung in Frame 13)

Figure 7: Four queries (Q1 to Q4) and the retrieved Top-1 strikes (R1 to R4) are illustrated for the similar billiards strike retrieval task, where the small "x" is the end point of the movement. For each strike, we provide the source of the strike, and the player who performs the strike in which frame.