Canonical publication: https://performstars.com/research/shot-difficulty/assessment-of-billiard-shot-difficulty.pdf

PERFORMSTARS · RESEARCH & ENGINEERING

Assessment of Billiard Shot Difficulty

A geometric formulation with reproducible calculations

Abstract. This paper defines geometric shot difficulty through the admissible interval of initial cue-ball directions. The formulation combines finite-segment pocket-entry constraints with an exact first-contact construction for two equal-radius balls. It provides explicit angular bounds, an inverse-tolerance score, equipment parameters for pool and snooker, and six worked positions. The equations and reference implementation permit independent reproduction of the calculations.

Dmitrii Sadovnik · PerformStars Research & Engineering · November 3, 2026

$$w = \beta_{max} - \beta_{min}$$

The full interval of initial cue-ball directions that permit the pot under the geometric model.
A narrower interval requires more precise aiming.

1. A shot has a window, not just an aiming line

Imagine two shots that both finish in the same pocket. In one, the cue ball is close to a straight object ball. In the other, the contact is thin and the object ball has a long way to travel. Both pots count as one successful shot, but the permitted error in the initial cue-ball direction can be very different.

The useful question is: **over what range of initial directions would the geometry still allow the pot?** A pocket has a finite opening. A ball has a finite radius. Those dimensions define a range of outgoing object-ball directions. The collision then maps that range back to a range of cue-ball directions.

This is possible without learning a player's accuracy. We are measuring a property of a specified position under a specified geometric model. Player skill, execution consistency, and the outcome remain separate observations.

The central quantity is the width w of that admissible interval, measured in radians. It combines pocket clearance, travel distances and contact geometry in a directly interpretable measure of aiming tolerance. A smaller w means a more demanding shot. The displayed difficulty score is an inverse rescaling of this tolerance.

2. What we collect from a recording

The detector does not predict the difficulty score. It supplies observations from which we reconstruct the position. The video pipeline is described in our article on ball detection and trajectory reconstruction.

1. **Locate the playing surface.** Table calibration maps perspective-distorted image coordinates into a rectangle attached to the playing field.

2. **Detect and track the balls.** Frame-indexed detections establish the cue-ball track, the candidate object ball, and their starting coordinates. The current calculation uses each track's first available point.
3. **Identify a pocket attempt.** Observed approaches to pocket regions provide candidate pockets. The selected ball, pocket, and contact geometry must support a feasible direct pot. A geometric score alone does not prove what the player intended.
4. **Apply physical dimensions.** The discipline supplies the ball radius and nominal pocket widths. The table dimensions convert the normalized positions into metres.
5. **Calculate, then store.** The geometric model returns the admissible interval of initial cue-ball directions and the corresponding difficulty score. The selected score is rounded to two decimal places when stored with the shot.

> $X = x_p \cdot \ell / 1280$
> $Y = y_p \cdot b / 640$

Here ℓ and b are the playing-field length and width, and (x_p, y_p) belongs to the normalized 1280×640 table rectangle—not to the original camera image. The two axes are scaled independently. Pocket widths and ball diameters stay fixed when the table size changes.

Some quantities, such as a sharply changing score near a tangential contact, are sensitive to coordinate error. Reporting two decimal places is a storage convention; it does not imply that the video measured the position with that level of physical certainty.

3. The complete geometry of a direct pot

We consider two equal-radius balls moving in a plane. The object ball initially rests at O; the cue ball starts at C. Under the ideal first-contact assumption, the object ball leaves along the line joining the centres at contact. The selected pocket is represented by a straight entrance segment. All lengths below use one consistent unit; all angles in the computation are in radians.

Symbols used in the equations

Symbol	Meaning
C, O; R	Initial cue-ball centre, object-ball centre, and common ball radius
$L = \lvert O - C \rvert$	Initial centre-to-centre separation; the model requires $L > 2R$
P; 2a	Midpoint of the pocket entrance and the full pocket-opening width
n; $t = (-n_y, n_x)$	Outward unit normal to the entrance line and its perpendicular unit tangent
x; h; d	Lateral offset, perpendicular distance, and distance from O to P
φ_-, φ_+; W	Feasible object-ball directions relative to n, and their full width
γ; β	Object-ball and cue-ball directions relative to the initial axis C → O
w; D	Width of the admissible interval of initial cue-ball directions and the resulting difficulty score

3.1. Local coordinates of the pocket entrance

$$E_- = P - at; \quad E_+ = P + at$$
$$x = (P - O) \cdot t; \quad h = (P - O) \cdot n$$
$$d = \sqrt{(x^2 + h^2)}; \quad \varphi = \operatorname{atan2}(x, h)$$

For a side pocket, the entrance segment is collinear with the cushion. For a corner pocket, the entrance is the diagonal segment joining the ends of the two adjacent cushions. If V is the corner vertex and n is the outward unit normal along the angle bisector, $\mathbf{P = V - an}$. The entrance endpoints $E_- = P - at$ and $E_+ = P + at$ lie on the adjacent cushion lines. The pocket ID identifies the table corner; P specifies the midpoint of the entrance segment.

Internally, the implementation divides every length by R, so the normalized ball radius becomes one. This changes numerical scale, not the geometry. Expressing the same inputs in millimetres instead of metres leaves the score unchanged.

3.2. Admissible angular interval for the object ball

Initially assume $x \geq 0$, $h > 0$, and $a > R$. A trajectory is admissible if the ball centre reaches the entrance line without the ball contacting either pocket edge before that intersection. The model evaluates the finite segment up to the intersection and excludes subsequent motion inside the pocket. Define $q = \sqrt{((x - a)^2 + h^2)}$, the distance from the initial centre to the nearer edge. If $q < R$, the initial position violates the required edge clearance and is rejected.

$$\varphi_+ = \operatorname{atan2}(x + a - R, h)$$

The lower angular bound is piecewise. For $x > a - R$, the limiting centre trajectory is tangent to the radius-R exclusion circle centred at the nearer pocket edge, with the contact occurring before the entrance line. For $x \leq a - R$, the limiting clearance is attained at the intersection with the entrance line:

$$\varphi_- = \operatorname{atan2}(x - a, h) + \operatorname{atan2}(R, \sqrt{(q^2 - R^2)}) \quad \text{when } x > a - R$$

$$\varphi_- = \operatorname{atan2}(x - a + R, h) \quad \text{when } x \leq a - R$$

Both expressions meet continuously at $x = a - R$, where $\varphi_- = 0$. For negative x, first calculate the interval at $|x|$, then reflect it:

$$I(-x, h) = [-\varphi_+(x, h), -\varphi_-(x, h)]$$
$$W = \varphi_+ - \varphi_-$$

The width of the admissible angular interval is $W = \varphi_+ - \varphi_-$. If $\varphi_+ \leq \varphi_-$, there is no interval of positive width and the calculation returns no score.

For the symmetric case $x = 0$, the result reduces to:

$$\varphi_+ = -\varphi_- = \operatorname{atan}((a - R) / d)$$
$$W = 2 \operatorname{atan}((a - R) / d)$$

These bounds define the finite-segment geometric formulation presented here by Dmitrii Sadovnik. The implementation evaluates the bounds directly. An equivalent difference-of-arctangents identity provides an independent algebraic check. With $x = d \sin\varphi$ and $h = d \cos\varphi$:

$$A = (x + a - R) / h; \quad B = (x - a) / h$$
$$\operatorname{atan}(A) - \operatorname{atan}(B)$$
$$= \operatorname{atan2}((2a - R)h, d^2 - a^2 + Ra - Rx)$$

Throughout this article, atan2(y, x) denotes the two-argument arctangent. Keeping both arguments preserves the quadrant; using atan(y/x) can select the wrong branch for a wide interval.

3.3. First-contact feasibility

Each direction satisfying the pocket-clearance constraints must also be attainable by the cue ball's first contact with the object ball. Let $e = (O - C)/L$ and let u be the specified unit direction of the object ball after contact. The corresponding cue-ball centre G at contact and the approaching-contact condition are:

$$G = O - 2Ru$$
$$(G - C) \cdot u > 0$$
$$\Leftrightarrow (O - C) \cdot u > 2R$$

The strict inequality selects approaching first contact rather than a geometrically intersecting position on the far side of the object ball. It is more restrictive than requiring an angle below 90° relative to the initial centre-to-centre direction.

$$\gamma_k = \operatorname{acos}(2R / L)$$
$$\delta = \operatorname{atan2}(e_x n_\gamma - e_\gamma n_x, e \cdot n)$$
$$[\gamma_-, \gamma_+] = ([\delta + \varphi_-, \delta + \varphi_+] + 2\pi k) \cap [-\gamma_k, \gamma_k]$$

Here γ is measured from e. Choose the equivalent angular interval using k = −1, 0, or 1; retain a positive-width intersection. Contact exactly at the endpoint is interpreted as a limit. If no intersection exists, the direct pot is geometrically infeasible under this model.

3.4. Initial cue-ball angular tolerance

In the frame aligned with C → O, the vector G − C has components (L − 2R cosγ, −2R sinγ). The required initial cue-ball direction is therefore:

$$\beta(\gamma) = \operatorname{atan2}(-2R \sin\gamma, L - 2R \cos\gamma)$$

Within the approaching-contact interval, this mapping is monotone decreasing:

$$d\beta/d\gamma = 2R(2R - L\cos\gamma) / (L^2 + 4R^2 - 4RL\cos\gamma) < 0$$

Monotonicity permits calculation of the initial cue-ball angular interval from its endpoint values: $\beta_{max} = \beta(\gamma_-)$ and $\beta_{min} = \beta(\gamma_+)$. Its full width is the geometric result:

$$w = \beta(\gamma_-) - \beta(\gamma_+)$$

$$= \operatorname{atan2}(-2R\sin\gamma_-, L - 2R\cos\gamma_-) - \operatorname{atan2}(-2R\sin\gamma_+, L - 2R\cos\gamma_+)$$

This interval contains the initial directions compatible with both pocket entry and approaching first contact. Its endpoints need not be symmetric about the direction aimed at the pocket centre. As the admissible interval narrows towards zero, the geometric demand increases.

For display, we use $D = 0.10/w$, with w in radians. The constant sets the numerical scale and does not affect shot ranking; before rounding, twice the score means half the angular tolerance.

The local error-amplification factor follows from the same derivative:

$$A(\gamma) = |d\gamma/d\beta| = (L^2 + 4R^2 - 4RL\cos\gamma) / [2R(L\cos\gamma - 2R)]$$

For a sufficiently short interval over which A is approximately constant, $w \approx (\gamma_+ - \gamma_-)/A$. The implementation evaluates the endpoint expressions exactly, without this local approximation, including intervals near the first-contact limit.

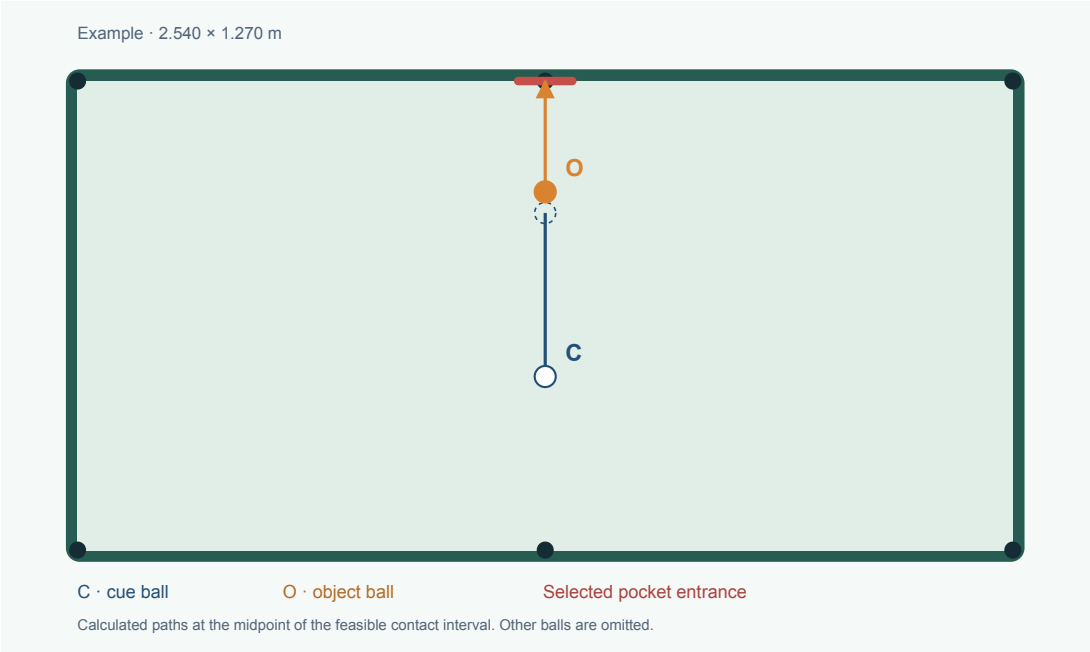
4. See the position, then check the calculation

The following six positions illustrate the calculation for different distances, cut angles, and equipment dimensions. Each diagram is followed by the difficulty score, the angular tolerances, and a numerical substitution into the formula.

Blue denotes the cue-ball path to contact; orange denotes the object-ball path for the midpoint of the admissible contact interval. C and O denote the ball centres.

EXAMPLE 01

A short, straight pool shot



GEOMETRIC DIFFICULTY

2.61

The admissible pocket-entry and first-contact angular intervals are symmetric about the centre line. Both angular deviations are included in the initial cue-ball tolerance.

Centre separation, L **0.5000 m**	Object → entrance centre, d **0.3000 m**
Object-ball angular tolerance, W **0.29794289 rad**	Cue-ball angular tolerance, w **0.0382482723 rad**

CALCULATION

`D = 0.10 / 0.0382482723 ≈ 2.61`

Use the unrounded input data to reproduce the final decimal places.

▼ **Coordinates and intermediate angles**

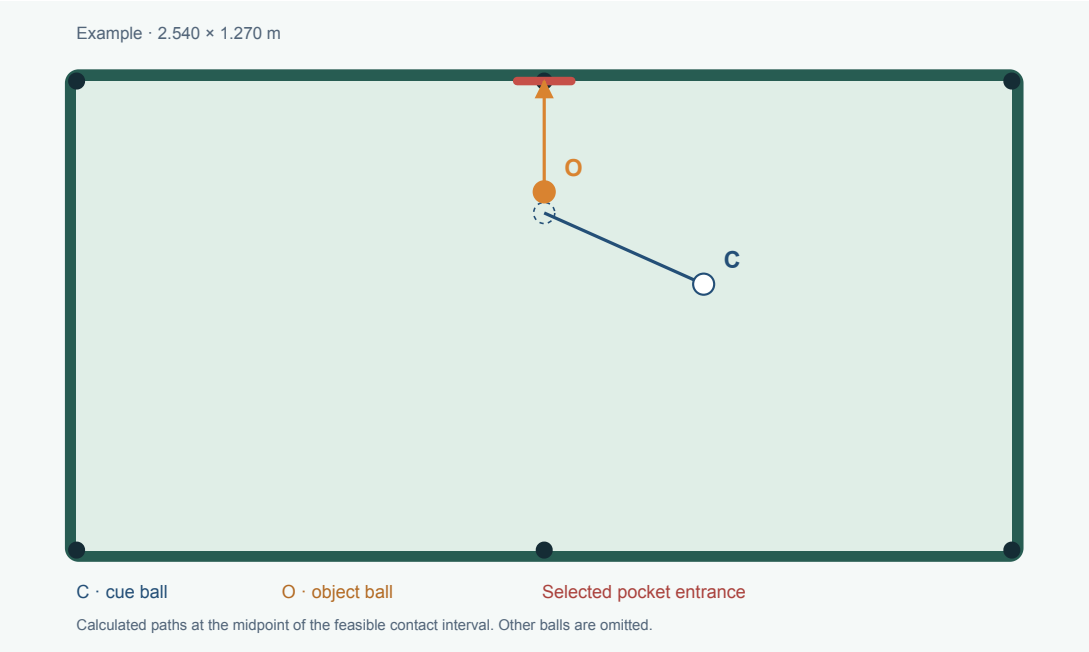
Metres: C = (1.27000000, 0.80000000); O = (1.27000000, 0.30000000); P = (1.27000000, 0.00000000). Ball radius R = 0.028575 m; pocket-opening width 2a = 0.147200 m.

x = 0.00000000 m; h = 0.30000000 m; δ = 0.000000000 rad.

$\varphi_- = -0.148971446$; $\varphi_+ = 0.148971446$ rad.
$\gamma_- = -0.148971446$; $\gamma_+ = 0.148971446$ rad.
$\beta(\gamma_-) = 0.0191241362$; $\beta(\gamma_+) = -0.0191241362$ rad.

EXAMPLE 02

Same pocket, same distances, a thinner cut



GEOMETRIC DIFFICULTY

6.85

The admissible object-ball angular interval is unchanged from example 1. The greater cut angle reduces the corresponding interval of initial cue-ball directions.

Centre separation, L **0.5000 m**	Object → entrance centre, d **0.3000 m**
Object-ball angular tolerance, W **0.29794289 rad**	Cue-ball angular tolerance, w **0.0145960140 rad**

CALCULATION

`D = 0.10 / 0.0145960140 ≈ 6.85`

Use the unrounded input data to reproduce the final decimal places.

▼ **Coordinates and intermediate angles**

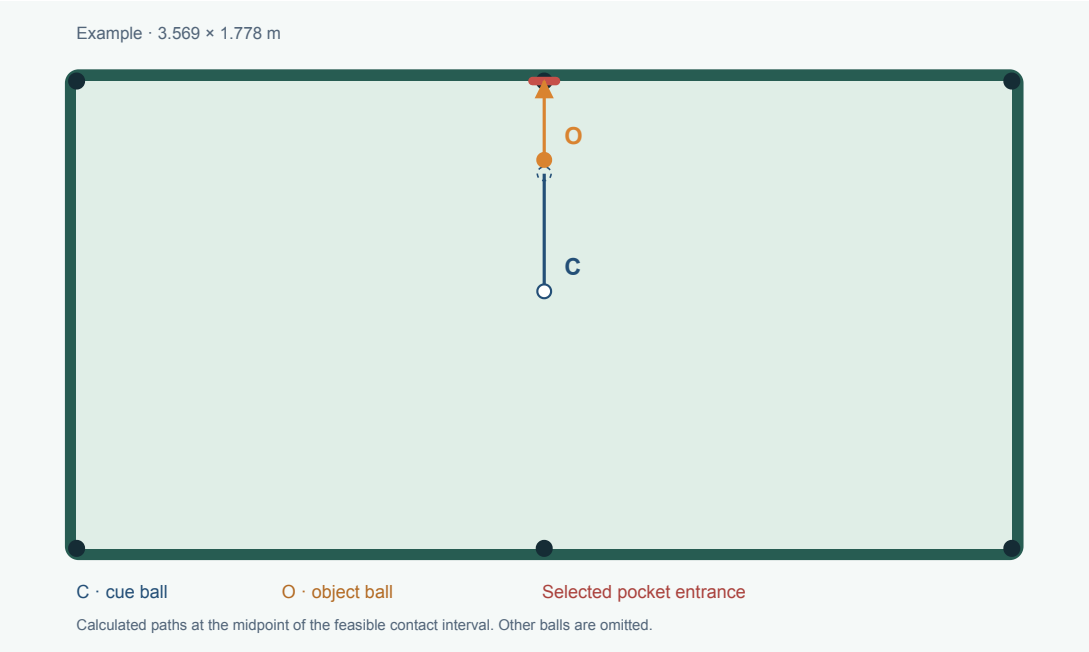
Metres: C = (1.70301270, 0.55000000); O = (1.27000000, 0.30000000); P = (1.27000000, 0.00000000). Ball radius R = 0.028575 m; pocket-opening width 2a = 0.147200 m.

x = 0.00000000 m; h = 0.30000000 m; δ = 1.047197551 rad.

$\varphi_- = -0.148971446$; $\varphi_+ = 0.148971446$ rad.
$\gamma_- = 0.898226105$; $\gamma_+ = 1.196168997$ rad.
$\beta(\gamma_-) = -0.0959671461$; $\beta(\gamma_+) = -0.1105631601$ rad.

EXAMPLE 03

The same metric position with snooker equipment



GEOMETRIC DIFFICULTY

6.83

The centre-to-centre separation remains 0.50 m and the object-to-entrance-centre distance remains 0.30 m. With a ball diameter of 52.5 mm and a 90 mm opening, the lateral clearance is 18.75 mm per side. The score is calculated with the same geometric equations and no discipline-specific multiplier.

Centre separation, L **0.5000 m**	Object → entrance centre, d **0.3000 m**
Object-ball angular tolerance, W **0.12483762 rad**	Cue-ball angular tolerance, w **0.0146326417 rad**

CALCULATION

$$D = 0.10 / 0.0146326417 \approx 6.83$$

Use the unrounded input data to reproduce the final decimal places.

▼ **Coordinates and intermediate angles**

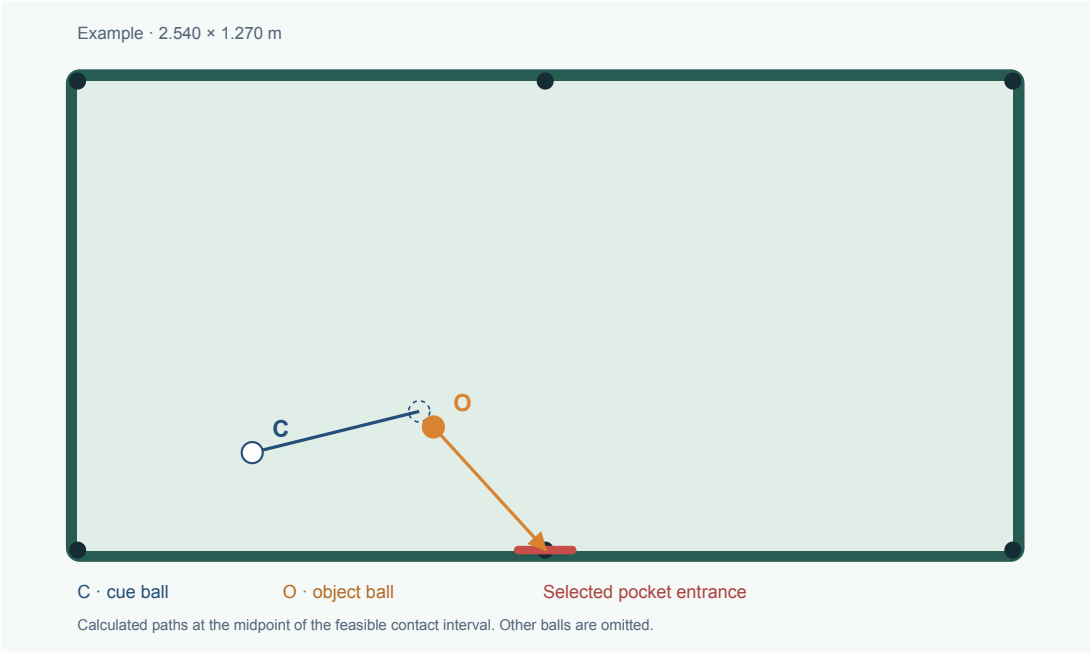
Metres: C = (1.78450000, 0.80000000); O = (1.78450000, 0.30000000); P = (1.78450000, 0.00000000). Ball radius R = 0.026250 m; pocket-opening width 2a = 0.090000 m.

x = 0.00000000 m; h = 0.30000000 m; δ = 0.000000000 rad.

$\varphi_- = -0.062418810$; $\varphi_+ = 0.062418810$ rad.
$\gamma_- = -0.062418810$; $\gamma_+ = 0.062418810$ rad.
$\beta(\gamma_-) = 0.0073163208$; $\beta(\gamma_+) = -0.0073163208$ rad.

EXAMPLE 04

A side-pocket cut



GEOMETRIC DIFFICULTY **12.80**

Half the admissible interval of initial cue-ball directions is approximately 0.224 degrees. The score follows directly from the geometry of the position.

Centre separation, L **0.4970 m**	Object → entrance centre, d **0.4509 m**
Object-ball angular tolerance, W **0.13321467 rad**	Cue-ball angular tolerance, w **0.0078096331 rad**

CALCULATION

`D = 0.10 / 0.0078096331 ≈ 12.80`

Use the unrounded input data to reproduce the final decimal places.

▼ **Coordinates and intermediate angles**

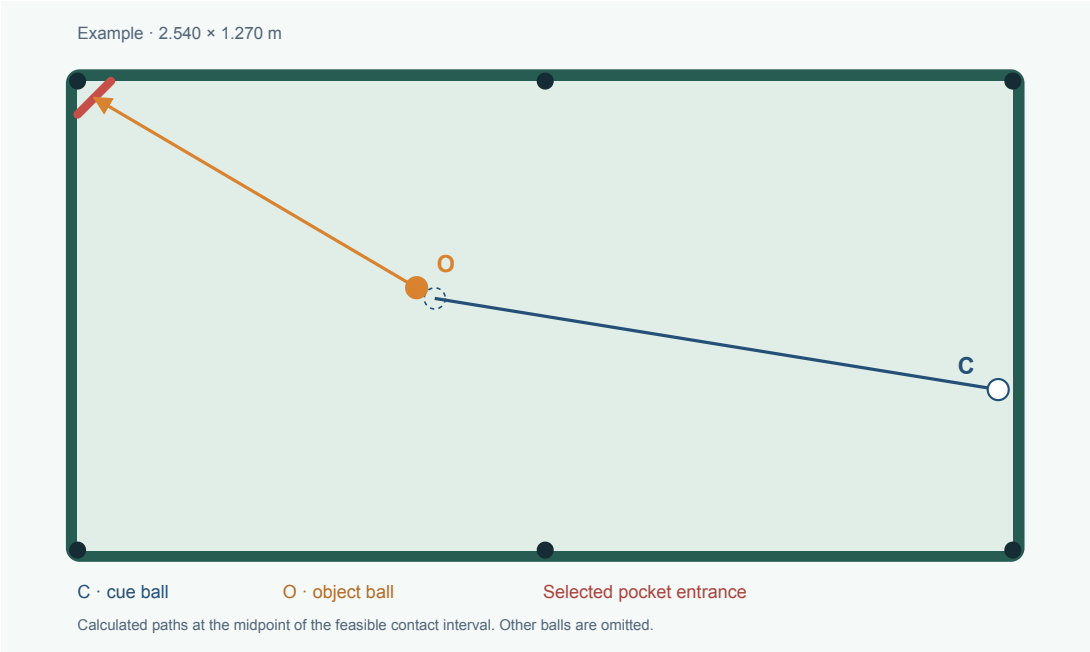
Metres: C = (0.47426563, 1.00607812); O = (0.96639063, 0.93662500); P = (1.27000000, 1.27000000). Ball radius R = 0.028575 m; pocket-opening width 2a = 0.147200 m.

x = -0.30360937 m; h = 0.33337500 m; δ = 1.710999425 rad.

$\varphi_- = -0.807768574$; $\varphi_+ = -0.674553906$ rad.
$\gamma_- = 0.903230851$; $\gamma_+ = 1.036445519$ rad.
$\beta(\gamma_-) = -0.0969214901$; $\beta(\gamma_+) = -0.1047311233$ rad.

EXAMPLE 05

A shot with a long cue-ball approach



GEOMETRIC DIFFICULTY

43.56

The long initial cue-ball travel distance produces a small angular tolerance despite the moderate cut angle.

Centre separation, L **1.6035 m**	Object → entrance centre, d **1.0154 m**
Object-ball angular tolerance, W **0.06682291 rad**	Cue-ball angular tolerance, w **0.0022954808 rad**

CALCULATION

`D = 0.10 / 0.0022954808 ≈ 43.56`

Use the unrounded input data to reproduce the final decimal places.

▼ **Coordinates and intermediate angles**

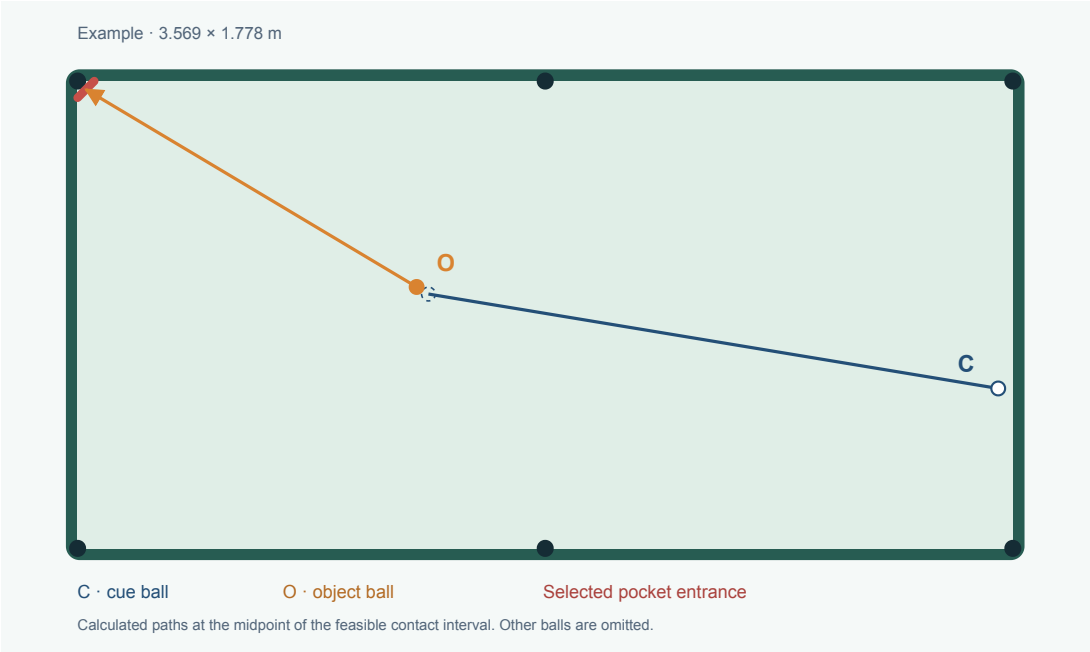
Metres: C = (2.50031250, 0.83542187); O = (0.92075000, 0.55959375); P = (0.04525483, 0.04525483). Ball radius R = 0.028575 m; pocket-opening width 2a = 0.128000 m.

x = -0.25537603 m; h = 0.98276110 m; δ = 0.612518206 rad.

φ_- = -0.287692988; φ_+ = -0.220870079 rad.
γ_- = 0.324825218; γ_+ = 0.391648127 rad.
$\beta(\gamma_-)$ = -0.0117718651; $\beta(\gamma_+)$ = -0.0140673459 rad.

EXAMPLE 06

The same relative position on a snooker table



GEOMETRIC DIFFICULTY

185.91

The cue ball, object ball and selected pocket occupy the same relative positions as in example 5. The larger snooker playing surface increases both travel distances, while the calculation uses 52.5 mm balls and a 90 mm pocket opening.

Centre separation, L **2.2528 m**	Object → entrance centre, d **1.4688 m**
Object-ball angular tolerance, W **0.02424907 rad**	Cue-ball angular tolerance, w **0.0005378837 rad**

CALCULATION

$$D = 0.10 / 0.0005378837 \approx 185.91$$

Use the unrounded input data to reproduce the final decimal places.

▼ **Coordinates and intermediate angles**

Metres: C = (3.51323438, 1.16959062); O = (1.29376250, 0.78343125); P = (0.03181981, 0.03181981). Ball radius R = 0.026250 m; pocket-opening width 2a = 0.090000 m.

x = -0.36085869 m; h = 1.42379779 m; δ = 0.613135511 rad.

$\varphi_- = -0.260556017$; $\varphi_+ = -0.236306944$ rad.
$\gamma_- = 0.352579494$; $\gamma_+ = 0.376828567$ rad.
$\beta(\gamma_-) = -0.0082271451$; $\beta(\gamma_+) = -0.0087650288$ rad.

Examples 5 and 6: the same relative position on pool and snooker tables

Parameter	Pool · example 5	Snooker · example 6
Playing surface	2.540 × 1.270 m	3.569 × 1.778 m
Ball diameter	57.15 mm	52.5 mm
Selected pocket opening	128.0 mm	90.0 mm
Cue-to-object centre separation	1.603 m	2.253 m
Object-to-entrance centre distance	1.015 m	1.469 m
Geometric difficulty	43.56	185.91

For this position, the snooker score is approximately 4.27 times the pool score. This is the combined effect of longer physical distances, the smaller ball diameter and the narrower pocket opening. It is a comparison of these two positions, rather than a fixed multiplier between disciplines. Relative coordinates are preserved along each table axis; the small difference in table aspect ratios is retained.

5. One geometric model, different equipment

A discipline enters the calculation through physical dimensions. Snooker uses the same equations as pool, with its own ball radius, pocket widths, and table dimensions. There is no manually chosen “harder game” multiplier. The parameters used in this article are:

Equipment parameters in the published implementation

Discipline	Ball diameter	Corner opening	Side opening
Pool	57.15 mm	128 mm	147.2 mm
Snooker	52.5 mm	90 mm	90 mm

The pocket-opening widths are specified model parameters rather than universal equipment dimensions. For snooker, 90 mm is the nominal width used in the straight-entrance approximation. Corner and side openings have separate configuration parameters, even when their values are equal. The curved profiles of the pocket facings and the pocket interior are excluded from this approximation.

Pool table dimensions vary with table size. The current snooker configuration uses a full-size 3.569 × 1.778 m playing field and a 52.5 mm ball. The WPBSA equipment rules specify the playing area and ball diameter; those values should not be confused with our simplified 90 mm pocket setting.

The ball radius R enters both the first-contact mapping and the pocket-clearance term a − R. The pocket half-width a directly affects the admissible object-ball angular interval. Example 3 holds the physical distances fixed, so its difference from example 1 is attributable to the specified equipment dimensions. At the same fractional table coordinates, a larger playing field additionally changes the physical distances.

In the straight examples above, pool gives D ≈ 2.61 and snooker D ≈ 6.83 for the same 0.50 m centre-to-centre separation and 0.30 m distance from the object-ball centre to the pocket-entrance centre. These values apply to the specified positions and opening widths; they do not establish a constant ratio between the disciplines.

Before rounding, equal scores across disciplines correspond to equal widths of the initial cue-ball angular intervals under these assumptions. Pocket-facing profiles, required shot speed, and stroke technique are excluded from this comparison.

6. Why smaller pockets matter: snooker and Heyball

For entry along the normal to the entrance line, the lateral clearance of the ball centre on either side equals half the difference between the opening width and the ball diameter:

> $m = a - R = (\text{pocket width} - \text{ball diameter}) / 2$
> $W = 2 \operatorname{atan}(m / d) \quad \text{when } x = 0$

The configured snooker dimensions give m = (90 − 52.5)/2 = 18.75 mm. The configured pool side opening gives m = (147.2 − 57.15)/2 = 45.025 mm. For the same perpendicular distance d, the smaller clearance yields a smaller value of W = 2 atan(m/d). The contact mapping then determines the initial cue-ball angular tolerance w using the corresponding radius R.

Per-side clearance in the current model and a separately identified Heyball equipment example

Equipment	Opening width	Ball diameter	Clearance m
Pool corner — configured	128 mm	57.15 mm	35.425 mm
Pool side — configured	147.2 mm	57.15 mm	45.025 mm
Snooker — configured approximation	90 mm	52.5 mm	18.750 mm
Heyball corner — BOJUE example	85 mm	about 57.2 mm	about 13.9 mm
Heyball side — BOJUE example	82 mm	about 57.2 mm	about 12.4 mm

Heyball equipment can combine a ball diameter close to that of pool with substantially smaller pocket openings. BOJUE documents an 85 mm corner / 82 mm side configuration for one tournament-focused setup, and also describes wider alternatives. These are manufacturer-specific examples rather than a universal Heyball standard. Opening widths must be measured between consistently defined pocket-edge reference points.

The underlying formula accepts explicit physical dimensions. For a measured pocket opening, the lower-level function takes the initial centres C and O, the entrance midpoint P, the outward normal n, the radius R, and the full opening width. For example, the following uses the manufacturer's approximate ball diameter and 85 mm corner opening:

```
import { difficalty } from './model.mjs';

// All positions and sizes are in metres.
// P is the entrance midpoint, not the table corner vertex.
const result = difficalty(C, O, P, 0.0572 / 2, 0.085, {
  normal: n
});
```

For an 82 mm side opening, use 0.082 m and the corresponding entrance midpoint and normal. This evaluates the specified equipment dimensions rather than a universal Heyball configuration. For both snooker and Heyball, the model excludes the curved profile of the pocket facings and ball interactions with those surfaces.

7. Where we use this in PerformStars

Difficulty adds context to the shot record. A coach can inspect the position, the outcome, and the geometric demand together, instead of treating every pot or miss as the same task.

Current uses of the difficulty field

Where	How the score is used
Individual shot review	The shot detail view displays the stored score as “Make difficulty” alongside the diagram and other metrics.
Workout summaries	The current aggregation counts shots with a score above 18 as complex shots, where a finite estimate is available.
Coaching reports	The report pipeline groups scored attempts into difficulty buckets and can examine made/miss counts within those groups.
Spreadsheet exports	The score is exported as Pocket complexity, allowing a coach or researcher to inspect the underlying shot records.

The present default report thresholds are easy ≤ 12, medium > 12 and ≤ 18, and hard > 18. These are configurable product groupings, not boundaries derived from geometry. The full numerical score retains more information than the group name.

We keep the distinction between a geometric input and an observed outcome. A high score does not certify a good stroke; a low score does not make a miss impossible. The value helps organize review, locate demanding attempts, and ask more specific coaching questions.

8. What the model leaves open

The model evaluates direct first contact followed by rectilinear motion to an idealized pocket-entrance segment. It excludes intervening balls, cushion-first shots, bank shots, rebounds from pocket facings, pocket depth, cloth friction, shot speed, spin, cue access near a cushion, and position for the next shot. Satisfying the geometric entrance criterion does not evaluate the subsequent pocketing dynamics.

Dependence on distance need not be globally monotone. At a fixed oblique angle to the entrance normal, increasing distance can initially produce a positive admissible interval where none existed because of the nearer pocket edge. Further increases can reduce its angular width. The relation D = 0.10/w is strictly decreasing for positive w.

The explicit equations permit independent reproduction of the calculation, variation of equipment parameters, and assessment of the geometric assumptions.

9. Reproduce the numbers

The reference implementation includes the scoring equations, equipment dimensions, and full-precision inputs for all six examples. The example runner evaluates direct pots in pool and snooker without external packages or a database connection.

Save all four files in the same folder and run the example runner with Node.js:

```
node verify.mjs
```

It prints the difficulty and the initial cue-ball angular tolerance for each illustration. To calculate another position, import `difficultyFromTablePoints`, pass the cue and object coordinates in the normalized 1280 × 640 rectangle, the pocket ID, table size, and discipline (`'pool'` or `'snooker'` for this article). Pocket IDs are 0 top-left, 1 top-middle, 2 top-right, 3 bottom-right, 4 bottom-middle, and 5 bottom-left.

```
import { difficultyFromTablePoints } from './model.mjs';

// 9-foot pool: physical field 2.54 × 1.27 m.
// C = (1.27, 0.80) m; O = (1.27, 0.30) m.
const result = difficultyFromTablePoints(
  { x: 640, y: 0.80 * 640 / 1.27 },
  { x: 640, y: 0.30 * 640 / 1.27 },
  1, 9, 'pool'
);

console.log(result.compl.toFixed(2)); // 2.61
console.log(result.cueAngularTolerance); // radians
```

Reference implementation: 2026-11-03. Scoring-source SHA-256: `b1d01303fe03316068677c8b921f131a0b5a26bf5d3be3b3800baf6b4e0faadf`. The digest identifies the server source; the standalone download uses a local equipment-module import.

Author and implementation provenance

Dmitrii Sadovnik · PerformStars Research & Engineering. The mathematical formulation, reference implementation, and numerical examples are provided together so that the calculation can be independently reproduced.

Continue reading: Teaching a Computer to Understand Billiards · Shot statistics.

References

1. Maurakh, Georgy. *Assessment of the Difficulty of a Billiard Shot*. April 2025. Source manuscript supplied to the project.

2. World Professional Billiards and Snooker Association. *Official Rules of the Games of Snooker and English Billiards*, 2024–25. Equipment dimensions. https://wpbsa.com/rules/.

3. BOJUE. *Heyball Pocket Size: Why 85 mm Corners Matter*. August 10, 2026. Manufacturer-specific equipment dimensions. Manufacturer specification.

4. Sadovnik, Dmitrii. Reference implementation and numerical inputs accompanying this paper. https://performstars.com/research/shot-difficulty.
