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Pawel Nurowski

nurowski@cft.edu.pl

Center for Theoretical Physics Polish Academy of Sciences: Centrum Fizyki Teoretycznej Polskiej Akademii Nauk <https://orcid.org/0000-0001-8534-7959>

Yuquanshan Jin

Technion – Israel Institute of Technology

Kevin Kenner

Frost School of Music, University of Miami, USA / Distinguished Juror, International Chopin Competition

Adam Sawicki

Center for Theoretical Physics

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A Proposed Modification of the Statistical Rules of the International Chopin Competition: A Quantitative Study and Mathematical Justification

Yuquanshan Jin^{2,3}, Kevin Kenner⁴, Paweł Nurowski^{1,2}, and Adam Sawicki^{1,2}

¹Guangdong Technion – Israel Institute of Technology, Guangdong, China

²Center for Theoretical Physics, Polish Academy of Sciences (PAS), Warsaw, Poland

³Technion – Israel Institute of Technology, Haifa, Israel

⁴Frost School of Music, University of Miami, USA / Distinguished Juror, International Chopin Competition

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Abstract

International piano competitions ask jurors to translate artistic judgements into numerical scores, but jurors do not all use the numerical scale in the same way. We propose a two-step method for combining their scores. First, each juror’s scoring scale is calibrated across all competitors without changing that juror’s ordering. Second, for each competitor, unusually distant calibrated scores are limited by repeated clipping until the mean stops changing. We prove that this iteration always converges. The method is tested on the complete published score sheets of the XIX Chopin Competition. The proposed rule leaves artistic judgement with the jurors and addresses only how their numerical scores are combined.

1 Introduction

An international music competition cannot, and should not, replace artistic judgement by statistics. Jurors must remain free to listen, compare, and make individual artistic decisions. But once those decisions are expressed by numbers, a different problem begins: how should the numbers be combined?

The scores naturally form a two-dimensional table, which we will call the *score matrix* and denote by X . We write $X_j(i)$ for the score given by juror j to competitor i . A column of X describes how one juror uses the numerical scale across competitors, while a row describes how the jury evaluates one competitor. Our proposal uses both directions: we first understand and align the jurors’ numerical scales, without changing their ordering of the competitors, and only then evaluate each competitor across the calibrated jury.

The proposed rule should be clear before its mathematical and statistical justification is developed. We therefore state it first.

The scoring rule we propose. At the stage r being evaluated, choose $0 < \kappa_0^{(r)} \leq \sqrt{2}$ for Step 0 and $\kappa_1^{(r)} \geq \sqrt{2}$ for Step 1. Once the score matrix X has been formed:

- 1. Align the jurors’ numerical scales.** For each juror j , compute the mean E_j and standard deviation σ_j of all valid scores in that juror’s column of X . Apply iterative clipping to the vector $(\sigma_1, \dots, \sigma_J)$, with the fixed width $c_J = \kappa_0^{(r)} s_\sigma$, where s_σ is the standard deviation of that vector, and denote the stabilized values by $\bar{\sigma}_j$. Calibrate every valid score by

$$Z_j(i) = (X_j(i) - E_j) \frac{\bar{\sigma}_j}{\sigma_j}.$$

This changes the numerical ruler used by the juror, but not the juror’s ordering of the competitors.

- 2. Evaluate each competitor across the calibrated jury.** For competitor i , take the valid calibrated scores $Z_1(i), \dots, Z_J(i)$, compute their standard deviation s_i , fix $c_i = \kappa_1^{(r)} s_i$, and repeatedly clip values farther than c_i from the evolving mean to the nearest boundary. Recompute the mean and continue until it stabilizes.
- 3. Use the limit as the result.** The converged mean is the competitor’s score obtained from that score matrix. An entry “S” is omitted whenever a juror does not evaluate that competitor.

In plain language: first make the jurors’ numerical scales comparable; then determine each competitor’s result by a convergent rule that limits the influence of unusually distant scores.

The order is essential. To answer the *row question* “How should this competitor be evaluated?”, we first use the perpendicular *column direction* to determine what the jurors’ numbers mean. The same iterative clipping rule is used in both directions. For every finite initial vector and every fixed clipping width $c > 0$, the iteration converges to a well-defined limit. We state this theorem in the main text, while its full projection-theoretic and Fejér-monotonicity proof is placed in Appendix A. The remainder of the article explains the statistical choices required by competition practice and tests the resulting rule on the four published stage score sheets of the XIX International Chopin Competition, including its effect on the ordering expressed by individual jurors.

The official score matrices on which the empirical analysis is based are reproduced in Tables C.1–C.4; see pp. 25–28. A flowchart summarizing the complete multi-stage procedure is given in Section 10; see Figure 1.

2 From the Current Rule to a Convergent Rule

Our proposal retains one feature of the present Chopin Competition rules: an individual score that lies far from the others is not discarded, but its influence on the aggregate result may be limited. The present rule implements this idea by a single clipping operation.

For a fixed competitor, let the valid scores be $x_1, \dots, x_m$ and let

$$\mu = \frac{1}{m} \sum_{r=1}^m x_r$$

be their preliminary arithmetic mean. In Stage I the official clipping width is $T = 3$ points; in Stages II and III and in the Final it is $T = 2$ points. A score above $\mu + T$ is replaced by $\mu + T$, a score below $\mu - T$ is replaced by $\mu - T$, and scores inside the interval are left unchanged. The adjusted scores are then averaged. Thus, for example, if the preliminary mean in a later stage were 20.00, a score of 25 would be replaced by 22.00, a score of 17 by 18.00, while scores between 18 and 22 would remain unchanged. This is the one-step adjustment prescribed in the official competition rules [1].

This rule is well defined, but the clipping boundaries are calculated from the *original* mean even though clipping changes some of the scores and therefore changes the mean. If the same correction is applied again, its interval will generally have a different centre. The official procedure stops after the first correction.

We remove this approximation by repeating the same operation. Starting from a finite vector $x^{(0)} = (x_1^{(0)}, \dots, x_m^{(0)})$ and a fixed clipping width $c > 0$, let $\mu^{(k)}$ be the mean after step k and set

$$x_r^{(k+1)} = \begin{cases} \mu^{(k)} + c, & x_r^{(k)} > \mu^{(k)} + c, \\ \mu^{(k)} - c, & x_r^{(k)} < \mu^{(k)} - c, \\ x_r^{(k)}, & \text{otherwise.} \end{cases}$$

Then recompute the mean and repeat. The question is immediate: does this process always settle, or can the moving mean generate an endless oscillation?

Convergence theorem. For every finite real initial vector and every fixed clipping width $c > 0$, the iterative clipping process converges to a stable limiting configuration. In particular, its evolving mean converges to a well-defined limiting value determined by the initial data and by c .

The full statement is Theorem A.1 on p. 16; its complete proof is given in Appendix A.

The simulations also show rapid convergence. In Monte Carlo tests with 10^5 independently generated jury-score configurations, fewer than ten iterations were typically sufficient at the practical tolerance 10^{-3} : the iteration-count distributions peaked at 7 steps for clipping widths $c = 1, 2, 3$, and at 5 steps even for the much wider test value $c = 7$. At the practical tolerance 10^{-3} , the modal iteration counts reported here are below ten. The complete numerical study, including tests at substantially higher accuracies, is given in Appendix B. The simulation protocol and the numerical values quoted here are given in Tables B.1 and B.2; the corresponding histograms are Figures B.1–B.3. See pp. 23–24.

The boxed convergence statement is a theorem, not a numerical observation. Its complete proof—using a zero-mean subspace, metric projections onto a convex box, nonexpansiveness, Fejér monotonicity, and a separate analysis of the motion of the mean—is given in Appendix A. The theorem and the numerical speed study have different logical roles: Appendix A proves that convergence occurs, whereas Appendix B measures how quickly the limit is reached in practice.

For the proposal, this means that every use of iterative clipping later in the paper has a well-defined limit. The theorem does *not*, however, decide which direction of the score table should be analysed, how different jurors’ numerical scales should be compared, or how the clipping width should be chosen in practice. These are questions about the two directions of the score table and about the statistical design of the rule.

3 One Score Table, Two Different Questions

The scores in one stage of a competition are naturally arranged in a matrix. Let $i = 1, \dots, N$ label the competitors and $j = 1, \dots, J$ the jurors, and write $X_j(i)$ for the score given by juror j to competitor i . Thus the competitors form the rows and the jurors the columns:

$$X = (X_j(i)) = \begin{array}{c|cccc} & J_1 & J_2 & \cdots & J_J \\ \hline C_1 & X_1(1) & X_2(1) & \cdots & X_J(1) \\ C_2 & X_1(2) & X_2(2) & \cdots & X_J(2) \\ \vdots & \vdots & \vdots & & \vdots \\ C_N & X_1(N) & X_2(N) & \cdots & X_J(N) \end{array}.$$

An entry marked “S” is omitted from the corresponding row and column calculations. The same table can now be read in two perpendicular directions, and the two readings answer different questions.

Fix a competitor: read across a row. For a fixed competitor i , the valid entries

$$C_i = (X_1(i), \dots, X_J(i))$$

compare the judgements of different jurors about the same performance. This is the direction in which the official Chopin Competition clipping rule operates: one fixes the competitor and asks whether an individual juror’s score is unusually far from the scores of the rest of the jury. It is also the direction in which our final competitor score will eventually be determined.

Fix a juror: read down a column. For a fixed juror j , the valid entries

$$J_j = (X_j(1), \dots, X_j(N))$$

answer a different question: how does this juror use the numerical scale across the competitors? One juror may use only a narrow part of the 1–25 range, while another may routinely use a much wider part. One may also score systematically higher or lower than another. Consequently, the same raw number need not occupy the same position in the numerical language of two different jurors.

This is why both directions of the table are used. Before comparing jurors horizontally for a fixed competitor, we first look vertically at each juror’s scores across competitors and determine the centre and spread of that juror’s numerical scale. The purpose is not to alter the juror’s artistic ordering of the competitors, but to make the numerical expressions of those orderings comparable. Only after this perpendicular calibration do we return to the rows and apply the convergent clipping procedure to evaluate each competitor across the jury.

The full analysis therefore has a directional cycle: we first use the *columns* to understand and align the jurors’ scales, then the *rows* to determine competitor scores, and finally return to the *columns* to check how much the rowwise correction has altered the ordering originally expressed by each juror.

For clarity, we first describe the complete procedure as if the competition consisted of a single stage. This allows us to explain the two operations on the score table without introducing the additional

notation required for combining several stages. Once the single-stage procedure has been fully defined and tested, we return to the actual multi-stage structure of the Competition and explain how the scores from the successive stages are combined.

4 Step 0: Understanding and Aligning the Jurors' Numerical Scales

The first step of the procedure acts in the juror direction. Fix juror J_j , and let

$$\mathcal{I}_j = \{i : X_j(i) \text{ is a numerical score}\}, \quad n_j = |\mathcal{I}_j|,$$

so that entries “S” are excluded. We summarize how this juror uses numbers by two quantities: the mean

$$E_j = \frac{1}{n_j} \sum_{i \in \mathcal{I}_j} X_j(i)$$

and the standard deviation

$$\sigma_j = \left[\frac{1}{n_j} \sum_{i \in \mathcal{I}_j} (X_j(i) - E_j)^2 \right]^{1/2}.$$

Thus E_j records where the juror places the centre of the numerical scale, whereas σ_j measures how widely that scale is used. The latter distinction matters: a juror who works almost entirely between, say, 18 and 20 is using the same 1–25 scoring system differently from a juror who routinely spreads scores over a much broader interval.

For each juror J_j , the subtraction of E_j from the scores $X_j(i)$ centres that juror's column around zero:

$$X_j(i) \mapsto X_j(i) - E_j.$$

This removes the difference between jurors who tend, on average, to use higher numerical scores and those who tend to use lower ones. It does not, however, remove a second difference between jurors: some use only a narrow part of the available numerical scale, whereas others spread their scores over a much wider range. This second feature is measured by the standard deviation σ_j of the scores given by juror J_j .

The numbers

$$\sigma_1, \dots, \sigma_J$$

therefore describe the widths of the numerical scales actually used by the J jurors. We regard them as a new data vector

$$\boldsymbol{\sigma}^{(0)} = (\sigma_1, \dots, \sigma_J).$$

This is the vector to which we now apply the same iterative-clipping procedure introduced in Section 2. To make the correspondence with the general construction explicit, write

$$m_{\sigma}^{(k)} = \frac{1}{J} \sum_{j=1}^J \sigma_j^{(k)}$$

for the mean of the current dispersion vector

$$\boldsymbol{\sigma}^{(k)} = (\sigma_1^{(k)}, \dots, \sigma_J^{(k)}).$$

From the initial vector $\boldsymbol{\sigma}^{(0)}$, let

$$s_{\sigma} = \left[\frac{1}{J} \sum_{j=1}^J (\sigma_j - m_{\sigma}^{(0)})^2 \right]^{1/2}$$

be its population standard deviation, and choose the fixed clipping width¹

$$c_J = \kappa_0^{(r)} s_{\sigma}, \quad 0 < \kappa_0^{(r)} \leq \sqrt{2}.$$

¹If $s_{\sigma} = 0$, all juror dispersions are already equal and this clipping step is unnecessary; we then set $\bar{\boldsymbol{\sigma}} = \boldsymbol{\sigma}^{(0)}$.

Thus c_J plays here exactly the role of the parameter c in the general clipping dynamics of Section 2, while the entries $\sigma_j^{(k)}$ play the role of the coordinates $x_j^{(k)}$ there.

At the k -th step, each current juror dispersion is compared with the interval

$$[m_\sigma^{(k)} - c_J, m_\sigma^{(k)} + c_J].$$

Accordingly,

$$\sigma_j^{(k+1)} = \begin{cases} m_\sigma^{(k)} + c_J, & \sigma_j^{(k)} > m_\sigma^{(k)} + c_J, \\ m_\sigma^{(k)} - c_J, & \sigma_j^{(k)} < m_\sigma^{(k)} - c_J, \\ \sigma_j^{(k)}, & \text{otherwise.} \end{cases}$$

The mean $m_\sigma^{(k+1)}$ is then recomputed and the procedure is repeated. By the convergence theorem stated in Section 2, the complete vector $\boldsymbol{\sigma}^{(k)}$ converges. We denote its limiting value by

$$\bar{\boldsymbol{\sigma}} = (\bar{\sigma}_1, \dots, \bar{\sigma}_J).$$

This operation does *not* force all jurors to use the same dispersion. A value σ_j that remains inside the successive clipping intervals is left unchanged; only a dispersion lying outside the collective range is moved towards that range. For example, with the retrospective choice $\kappa_0^{(r)} = \sqrt{2}$, in the Final-stage data considered below, one juror has an initial dispersion of approximately 0.88. It is the only dispersion lying below the lower clipping boundary and is moved to approximately 1.27, whereas the other jurors' dispersions are not altered. The complete juror-by-juror calculation is given in Table D.1 on p. 28; the initial and stabilized vectors are displayed in Table D.2 on p. 29.

Each valid raw score is then transformed to²

$$Z_j(i) = (X_j(i) - E_j) \frac{\bar{\sigma}_j}{\sigma_j}.$$

This has two exact effects. The transformed scores of juror J_j have mean zero and standard deviation $\bar{\sigma}_j$; at the same time, the juror's ordering of competitors is preserved. Indeed, for any two competitors C_i and C_h evaluated by J_j ,

$$Z_j(i) - Z_j(h) = \frac{\bar{\sigma}_j}{\sigma_j} (X_j(i) - X_j(h)),$$

and the prefactor is positive.

What Step 0 changes—and what it does not. Step 0 changes the numerical ruler used by a juror: it recentres the scores and, when necessary, moderates an unusually narrow or wide scale. It does *not* change which competitors that juror places above, below, or equal to one another. The ordering in every juror column is therefore preserved exactly at this stage.

Only after this perpendicular calibration do we turn back to the rows and ask for the collective result of each competitor across the now aligned jury.

5 Step 1: Evaluating Each Competitor Across the Calibrated Jury

Step 0 used the columns of the score table to put the jurors' numerical scales on a comparable footing. We now turn through ninety degrees and work across the rows. Fix a competitor C_i , and let

$$\mathcal{J}_i = \{j : X_j(i) \text{ is a numerical score}\}, \quad q_i = |\mathcal{J}_i|,$$

so that a juror whose entry for this competitor is “S” is again omitted. The data to be combined are no longer the raw scores $X_j(i)$, but the calibrated scores obtained in Step 0:

$$\mathbf{Z}_i^{(0)} = (Z_j(i))_{j \in \mathcal{J}_i}.$$

²If $\sigma_j = 0$, then all valid scores in that juror's column are equal. In this degenerate case we set $Z_j(i) = 0$ for every valid entry in the column and no division is performed. In the discussion below we therefore assume $\sigma_j > 0$.

Each entry now measures the competitor's position relative to the numerical scale actually used by the corresponding juror. This is why the columnwise calibration had to precede the rowwise evaluation.

Let

$$\mu_i^{(0)} = \frac{1}{q_i} \sum_{j \in \mathcal{J}_i} Z_j(i)$$

be the initial mean of this calibrated row, and let

$$s_i = \left[\frac{1}{q_i} \sum_{j \in \mathcal{J}_i} (Z_j(i) - \mu_i^{(0)})^2 \right]^{1/2}$$

be its population standard deviation. We choose the fixed clipping width³

$$c_i = \kappa_1^{(r)} s_i, \quad \kappa_1^{(r)} \geq \sqrt{2}.$$

The choice of the admissible multipliers is discussed in the next section. Here c_i is fixed from the initial calibrated row and plays exactly the role of the fixed parameter c in the general dynamics of Section 2.

To make this correspondence explicit, denote the current row after k clipping steps by

$$Z_i^{(k)} = (Z_j^{(k)}(i))_{j \in \mathcal{J}_i}, \quad \mu_i^{(k)} = \frac{1}{q_i} \sum_{j \in \mathcal{J}_i} Z_j^{(k)}(i).$$

Starting from $Z_j^{(0)}(i) = Z_j(i)$, update each valid entry by

$$Z_j^{(k+1)}(i) = \begin{cases} \mu_i^{(k)} + c_i, & Z_j^{(k)}(i) > \mu_i^{(k)} + c_i, \\ \mu_i^{(k)} - c_i, & Z_j^{(k)}(i) < \mu_i^{(k)} - c_i, \\ Z_j^{(k)}(i), & \text{otherwise.} \end{cases}$$

The mean $\mu_i^{(k+1)}$ is then recomputed and the process is repeated. In the notation of Section 2, the coordinates $x_r^{(k)}$ are here the calibrated juror scores $Z_j^{(k)}(i)$, the evolving mean $\mu^{(k)}$ is $\mu_i^{(k)}$, and the clipping width c is c_i . The convergence theorem therefore applies directly.

We define the final score of competitor C_i in the stage by

$$\bar{Z}(i) = \lim_{k \rightarrow \infty} \mu_i^{(k)}.$$

No juror's score is discarded: scores inside the current interval $[\mu_i^{(k)} - c_i, \mu_i^{(k)} + c_i]$ remain untouched, while a score outside the interval is moved only to the nearest boundary. The centre of that interval is then updated and the same rule is repeated until the stable limit is reached. A complete Final-stage illustration of this step is supplied by the calibrated matrix in Table D.3, the full calculation for Book Number 62 in Table D.4, and the resulting Final-stage matrix in Table D.5; see pp. 29–30.

What changes in Step 1. Step 0 preserved every juror's ordering of competitors exactly. Step 1 has a different purpose: it limits the influence of an individual calibrated score that is extreme relative to the other jurors evaluating the same competitor. Consequently, this is the first stage of the procedure that can alter an individual juror's numerical ordering. How often such an alteration represents a genuine change of that ordering—rather than merely the resolution of a tie—will be tested explicitly against the complete competition data below.

The construction is now complete except for the choice of the two clipping-width multipliers. We address this next.

³If $s_i = 0$, then all valid calibrated scores for C_i are equal, so no clipping is required and the final score is simply their common value. Hence the iterative case considered below has $s_i > 0$ and therefore $c_i > 0$.

6 Choosing the Clipping Widths

In the preceding two sections we expressed the clipping widths in terms of the standard deviations of the initial vectors. At the stage r being evaluated, in Step 0 we set

$$c_J = \kappa_0^{(r)} s_\sigma, \quad 0 < \kappa_0^{(r)} \leq \sqrt{2}$$

for the vector of juror dispersions, while in Step 1 we set

$$c_i = \kappa_1^{(r)} s_i, \quad \kappa_1^{(r)} \geq \sqrt{2}$$

for the calibrated scores of competitor C_i . The two constants may differ from one another and may be chosen separately for each competition stage.

The convergence theorem of Section 2 does not prescribe a particular clipping width: the iteration converges for every fixed $c > 0$. The choice of c is therefore not a question of convergence, but of how strongly the scoring rule is allowed to modify the information supplied by the jury. A very narrow clipping interval would classify many ordinary differences of opinion as outliers. A very wide interval, on the other hand, would leave isolated extreme scores almost unaffected. We want the clipping width to react to the actual spread of the data, while at the same time controlling how much of the jury data can initially be subject to correction.

For this reason we write the clipping width in the form

$$c = ks,$$

where s is the population standard deviation of the *initial* vector to which the clipping procedure is applied. Once c has been determined, it is kept fixed throughout the subsequent iteration, as required by the dynamics of Section 2. The factor s makes the clipping width relative to the observed spread: the same absolute numerical distance should not be treated in the same way in a tightly clustered set of scores and in a widely dispersed one. The dimensionless parameter k then determines how selective the correction is.

Chebyshev's inequality gives a distribution-free bound. For any finite data vector

$$y_1, \dots, y_m$$

with mean μ and positive population standard deviation s , Chebyshev's inequality gives

$$\frac{1}{m} \#\{r : |y_r - \mu| \geq ks\} \leq \frac{1}{k^2}.$$

In the present context this has a direct practical meaning. Before the iteration starts, no more than a fraction $1/k^2$ of the entries can lie at least k standard deviations from the mean. Since our clipping rule modifies only entries lying strictly outside the interval

$$[\mu - ks, \mu + ks],$$

the same bound applies, a fortiori, to the fraction of entries that can be modified in the first clipping step.

For Step 1, $k = \kappa_1^{(r)} \geq \sqrt{2}$, so this bound is at most one half. Thus, irrespective of the shape of the distribution, the first Step 1 clipping operation cannot treat more than one half of the calibrated scores as lying outside its window. The choice $\kappa_1^{(r)} = \sqrt{2}$ is the narrowest admissible Step 1 window under this constraint; larger values make clipping less frequent.

In Step 0 the data are

$$\sigma_1, \dots, \sigma_J,$$

the widths of the numerical scales used by the individual jurors. The bound here is $1/(\kappa_0^{(r)})^2$. Its upper restriction $\kappa_0^{(r)} \leq \sqrt{2}$ keeps the Step 0 window from becoming so wide that unusually narrow or wide juror scales are left largely unchanged. The one-half bound in Step 0 holds at the particular

choice $\kappa_0^{(r)} = \sqrt{2}$, but need not hold for a smaller value. In Step 1, for a fixed competitor C_i , the data are the calibrated scores

$$Z_j(i), \quad j \in \mathcal{J}_i.$$

Here the bound $1/(\kappa_1^{(r)})^2 \leq 1/2$ limits the fraction of the jury whose scores for that competitor can initially lie outside the clipping window.

This worst-case bound applies to the initial clipping step, not to the complete iteration. Chebyshev’s inequality controls the fraction of entries lying beyond the threshold at the *initial* clipping step; it does not by itself place the same bound on the total number of entries that may be modified after the centre of the clipping interval has moved during subsequent iterations. The latter is an empirical question, and we examine it directly using the complete data of the XIX Competition.

For orientation, at the particular multiplier $\sqrt{2}$, if the data happened to follow a normal distribution, then only

$$\Pr(|Y - \mu| \geq \sqrt{2}s) = 2(1 - \Phi(\sqrt{2})) \approx 0.1573$$

of the observations—about 15.73%—would lie beyond the same $\sqrt{2}s$ threshold. We do *not* assume normality in deriving or applying our rule; this number is only a familiar reference point. In the retrospective analysis of the XIX Competition, the largest stagewise proportion of calibrated competitor scores actually modified by Step 1 is about 17%. The full stage-by-stage results are presented below. The exact stagewise counts and percentages are collected in Table E.1 on p. 30.

The roles of the two parameters. The convergence theorem holds for every fixed clipping width $c > 0$. Writing $c = ks$ makes this width relative to the observed spread of the data. At stage r , $0 < \kappa_0^{(r)} \leq \sqrt{2}$ controls the calibration of juror scales, while $\kappa_1^{(r)} \geq \sqrt{2}$ controls rowwise score clipping. Increasing either multiplier makes clipping less frequent. Chebyshev’s initial bound is $1/k^2$, and is at most one half for every admissible Step 1 multiplier. The choice $\kappa_0^{(r)} = \kappa_1^{(r)} = \sqrt{2}$ is admissible for both steps.

The scoring procedure is specified once the two admissible multipliers have been chosen for the stage being evaluated. We turn next to a separate question: how much does this procedure alter the ordering of the competitors originally expressed by an individual juror?

7 How Much Does the Procedure Alter a Juror’s Ordering?

A juror does not merely assign isolated numbers. Taken together, the scores in one juror’s column express an ordering of the competitors, possibly with ties. If juror J_j gives competitor C_a a higher score than competitor C_b , then J_j has explicitly placed C_a above C_b .

Step 0 preserves this ordering exactly, but Step 1 acts in the perpendicular direction: for each competitor it compares the calibrated scores across the jury and may modify some individual entries. When the corrected table is then read again down a juror’s column, the order may no longer be exactly the one that the juror originally entered. This matters in practice. A published correction procedure should not routinely make it appear that a juror preferred C_b to C_a when the juror’s own scores said the opposite. We therefore ask:

How often does the rowwise correction of Step 1 genuinely change the ordering of competitors expressed by an individual juror?

The qualifier *genuinely* is needed because jury scores contain many ties. If three competitors receive the same highest score from one juror, that juror has placed all three in a common top group, not in a definite first–second–third order. If Step 1 later resolves this tie while keeping all three within positions 1–3, no expressed preference has been reversed. A genuine alteration occurs only when the correction carries a competitor outside the range of positions allowed by the original tie.

7.1 Tie ranges and genuine rank alterations

To decide whether a juror’s ordering has really been changed, we first have to describe exactly what the juror’s original scores say about the position of each competitor. It is useful to do this in ordinary

language before introducing notation.

Fix a juror J_j and a competitor C_i . First count how many competitors received from J_j a score *strictly higher* than the score of C_i . Suppose there are q of them. Then those q competitors must appear above C_i , so the best position that C_i can occupy is

$$q + 1.$$

Now look at the competitors who received exactly the same score as C_i . Suppose there are t of them in total, including C_i itself. The juror has placed these t competitors in one tied group and has not specified their order inside that group. They therefore occupy, collectively, the positions

$$q + 1, q + 2, \dots, q + t.$$

For C_i , the original score permits any position from $q + 1$ through $q + t$. We call this interval of permitted positions the competitor's *tie range* for juror J_j .

For example, if three competitors all receive the highest score from one juror, nobody is ranked strictly above them, so $q = 0$, and the tied group has size $t = 3$. Each of the three therefore has the tie range

$$[1, 3].$$

If Step 1 later places these three competitors first, second, and third, the procedure has merely resolved a tie that the juror left unresolved. If one of them is moved to fourth place, however, the procedure has crossed the boundary of the ordering information actually supplied by the juror.

We now introduce notation for this construction. Let

$$q_{ji} = \#\{h \in \mathcal{I}_j : X_j(h) > X_j(i)\}$$

be the number of competitors to whom juror J_j gave a strictly higher score than to C_i , and let

$$t_{ji} = \#\{h \in \mathcal{I}_j : X_j(h) = X_j(i)\}$$

be the number of competitors sharing the same score as C_i , including C_i itself.

The highest and lowest positions compatible with the juror's original scores are therefore

$$r_{ji}^- = q_{ji} + 1, \quad r_{ji}^+ = q_{ji} + t_{ji}.$$

Here r_{ji}^- is the *best* position permitted by the original scores, while r_{ji}^+ is the *worst*. This is why $r_{ji}^- \leq r_{ji}^+$. Equivalently,

$$r_{ji}^- = 1 + \#\{h \in \mathcal{I}_j : X_j(h) > X_j(i)\}, \quad r_{ji}^+ = \#\{h \in \mathcal{I}_j : X_j(h) \geq X_j(i)\}.$$

We write

$$I_{ji} = [r_{ji}^-, r_{ji}^+]$$

for the tie range of competitor C_i in the ordering expressed by juror J_j .

Step 0 does not change these tie ranges. For a fixed juror, Step 0 applies the same positive affine transformation to every score in that juror's column. A higher score remains higher, a lower score remains lower, and equal scores remain equal.

We can now ask what Step 1 does to this ordering. Let

$$\hat{Z}_j(i) = \lim_{k \rightarrow \infty} Z_j^{(k)}(i)$$

be the score remaining in juror J_j 's column after the rowwise clipping for competitor C_i has converged, and let $\hat{r}_{ji}$ denote the resulting position of C_i in that juror's corrected ordering.

We count a *genuine rank alteration* only if two things happen simultaneously.

First, Step 1 must actually have changed the score:

$$\hat{Z}_j(i) \neq Z_j(i).$$

Second, after that change the competitor must end outside the range of positions permitted by the juror’s original score:

$$\hat{r}_{ji} \notin I_{ji}.$$

Both conditions are necessary. Consider again a three-way tie for first place. If one of the three tied competitors is modified by Step 1 but still ends in position 1, 2, or 3, the procedure has not contradicted the juror’s expressed ordering. The original tie allowed all three positions. If that competitor falls to position 4, however, the original tie range has been crossed and we count a genuine alteration.

There is one further point. A competitor whose own score is not changed may nevertheless move in the ordering because the score of another competitor has been corrected. We do not count this passive movement as a second alteration. The change is attributed to the entry on which the procedure actually acted; otherwise the same correction would be counted twice.

What counts as a genuine alteration. For each juror and competitor, the original scores determine a range of permitted positions, not necessarily a single position. A correction counts as a genuine alteration only if the competitor’s own score is modified *and* its resulting position falls outside that original tie range. Breaking a tie inside its permitted range does not count, and neither does the passive movement of an untouched score.

This definition gives a quantity with a direct interpretation: it measures how often the rowwise correction makes an active change that places a competitor outside the ordering information actually supplied by an individual juror. We now compute this quantity for all four stages of the XIX International Chopin Competition.

8 Rank Integrity in the XIX Competition Data

We can now return to the question posed at the beginning of Section 7 and answer it using the complete analysis of the XIX Competition⁴. All retrospective calculations in this article use the admissible choice $\kappa_0^{(r)} = \kappa_1^{(r)} = \sqrt{2}$ at every stage. For every stage, the score table was examined juror by juror after Step 1. Two numbers were recorded separately: how many individual scores had been changed by the clipping procedure, and how many of these changes actually carried a competitor outside the tie range allowed by that juror’s original scores. Only the latter are counted as *genuine rank alterations*.

The results obtained in the four stages are summarized below.

Stage	Scores clipped	Genuine rank alterations	Total scores	Alteration rate
I	215	64	1395	4.59%
II	115	21	667	3.15%
III	54	14	331	4.23%
Final	27	3	182	1.65%

The same aggregate results, including the fraction of all entries modified by Step 1, are given in Table E.1 on p. 30. Complete juror-by-juror results appear in Tables E.2–E.5, beginning on p. 30.

Thus, in every stage, fewer than 5% of all juror–competitor score entries qualify as genuine rank alterations under the definition in Section 7.1. This is a much stronger statement than merely observing that only a modest number of scores are clipped. Step 1 is allowed to change an individual numerical score when that score lies outside the accepted window, but in the large majority of such cases the correction does not push the competitor beyond the ordering information actually supplied by the juror.

The Final provides a useful concrete example of why the two counts differ. For juror J_5 , Book Numbers 57, 73, and 29 all received the same highest raw score, 24, and therefore shared the tie

⁴Consistently with the single-stage presentation adopted in Section 3, the diagnostic calculations in this section apply Steps 0 and 1 separately to each of the four published stage matrices. Their purpose is to measure, stage by stage, how strongly the correction affects individual juror scores and the orderings expressed by the jurors. Section 10 explains separately how the raw scores from successive stages are combined when a cumulative competition result is required.

range $[1, 3]$. After the correction, Book Numbers 73 and 29 remained inside that range, whereas Book Number 57 moved to rank 4. The first two changes merely resolved the original tie; the last one crossed its boundary and was therefore counted as one genuine alteration. The same juror also had ties occupying ranks $[8, 9]$ and $[10, 11]$; their post-correction order was resolved inside the original ranges and hence produced no genuine alteration. The three calculations are displayed in Tables E.6–E.8; see p. 31.

Empirical rank-integrity result. With the tie-aware definition of Section 7.1, the genuine rank-alteration rate is 4.59% in Stage I, 3.15% in Stage II, 4.23% in Stage III, and 1.65% in the Final. In particular, it remains below 5% in all four stages of the XIX Competition.

These figures address a specific and reproducible question: how often the rowwise correction actively moves a competitor outside the range of positions expressed by an individual juror’s original scores. They should not be interpreted as a numerical measure of the full artistic content of a juror’s judgement. Detailed juror-by-juror results are given in Tables E.2–E.5, beginning on p. 30.

The low alteration rates also allow us to test whether a more elaborate calibration could improve rank preservation further. During the development of the method, a nonlinear logarithmic dampening was examined to test this question. We turn to that comparison next.

9 Testing an Alternative: Logarithmic Dampening

Section 8 shows that, with the linear Step 0 calibration followed directly by the rowwise clipping of Step 1, genuine rank alterations remain below 5% in every stage of the XIX Competition. During the development of the procedure, we tested whether this number could be reduced further by inserting one additional transformation between Step 0 and Step 1. The supporting counts are given in Tables E.1–E.5; see pp. 30–31.

The question was specific. After Step 0, an unusually large positive or negative calibrated score $Z_j(i)$ may still lie far from the other jurors’ scores for the same competitor and may therefore be clipped in Step 1. One can first compress the magnitude of such scores, while leaving small calibrated scores almost unchanged, and only then apply the same rowwise clipping procedure. The logarithmic transformation tested for this purpose was

$$\tilde{Z}_j(i) = \text{sgn}(Z_j(i)) \bar{\sigma}_j \ln \left(1 + \frac{|Z_j(i)|}{\bar{\sigma}_j} \right).$$

For a fixed juror J_j , this transformation is strictly increasing as a function of $Z_j(i)$. It therefore does not change that juror’s ordering of the competitors at the moment when it is applied: if $Z_j(a) > Z_j(b)$, then also $\tilde{Z}_j(a) > \tilde{Z}_j(b)$. At the same time it reduces numerical separations, with a stronger effect on values farther from zero. Indeed, away from zero its slope is

$$\frac{\bar{\sigma}_j}{\bar{\sigma}_j + |Z_j(i)|} \leq 1.$$

Thus the logarithmic step preserves the order produced by Step 0 but compresses the scale before Step 1.

The comparison with the linear procedure was then made with everything else unchanged: Step 1 was applied to the logarithmically transformed rows, and the number of scores modified by Step 1 and genuine rank alterations was counted by the same criteria as before. The reported results are:

Stage	Linear Step 0		Linear Step 0 + logarithmic dampening	
	Scores clipped	Genuine alterations	Scores clipped	Genuine alterations
I	215	64	214	79
II	115	21	100	28
III	54	14	52	17
Final	27	3	26	4

The aggregate comparison is reproduced in Table F.1 on p. 32. Complete juror-by-juror comparisons are given in Tables F.2–F.5; see p. 32.

In all four stages, the logarithmic transformation slightly reduces the number of scores modified by Step 1, but it increases the number of genuine rank alterations in every stage. These two quantities therefore measure different things: reducing the number of scores modified by Step 1 does not by itself imply better preservation of the ordering expressed by individual jurors.

The result is also consistent with the mathematical effect of the transformation. Before Step 1 the logarithmic map preserves the order in each juror’s column, but it decreases the numerical gaps between scores. The subsequent rowwise corrections therefore act on a table in which some neighbouring competitors are separated by smaller margins. A correction that would not cross an ordering boundary in the linearly calibrated table may cross one after this compression. The comparison above shows that, on the XIX Competition data, this loss of numerical separation outweighs the small reduction in the number of scores modified by Step 1.

Conclusion of the logarithmic test. The additional logarithmic transformation was introduced to test whether the final rowwise correction could preserve the jurors’ orderings better. It does not: the number of genuine rank alterations increases in all four stages. We therefore retain the procedure stated on the first page: linear juror-scale alignment in Step 0, followed directly by convergent rowwise clipping in Step 1.

The final procedure has now been defined and tested against the two questions that motivated its construction: control of extreme numerical scores and preservation of the ordering expressed by individual jurors. We now return to the actual multi-stage structure of the Competition and explain how the raw scores from successive stages are combined before this same procedure is applied.

10 Combining the Successive Stages

Up to this point we have deliberately described the procedure as if the competition consisted of a single stage. We now explain how the same rule is used when the result of a later stage is required to take the earlier stages into account.

The important point is that the stages are combined *before* Step 0 and Step 1 are applied. We do not calculate a separate calibrated final score for each stage and then average those final scores. Instead, we first combine the original jury scores from the relevant stages, using the prescribed stage weights. The resulting table is then treated as the single score matrix X considered throughout Sections 3–9.

Let $X^{(r)}$ denote the matrix of original jury scores in stage r , after restricting it to the competitors who have reached the stage currently being evaluated. A juror–competitor pair marked “S” is omitted from the cumulative calculation, exactly as in the single-stage case. Thus the weighted sum below is formed only for numerical juror–competitor entries. The stage weights themselves are not changed by our proposal: they are the weights prescribed by the competition rules [1]. If the prescribed weights of the stages are

$$w_1, \dots, w_W, \quad w_r \geq 0, \quad \sum_{r=1}^W w_r = 1,$$

then the score table used for the cumulative evaluation at stage W is

$$X = \sum_{r=1}^W w_r X^{(r)}.$$

For the XIX Competition, the prescribed cumulative score matrices are therefore

$$\text{Stage I:} \quad X = X^{(1)},$$

$$\text{Stage II:} \quad X = 0.30 X^{(1)} + 0.70 X^{(2)},$$

$$\text{Stage III:} \quad X = 0.10 X^{(1)} + 0.20 X^{(2)} + 0.70 X^{(3)},$$

$$\text{Final:} \quad X = 0.10 X^{(1)} + 0.20 X^{(2)} + 0.35 X^{(3)} + 0.35 X^{(4)}.$$

At each stage, Step 0 and Step 1 are applied only after the corresponding matrix X has been formed. At the stage W being evaluated, these steps use $\kappa_0^{(W)}$ and $\kappa_1^{(W)}$, respectively. The resulting converged row means determine the cumulative ranking at that stage.

This order of operations is essential. The stage weights are applied to the original scores, which are all expressed on the common competition scale. Calibration and clipping are performed only after these weighted raw scores have been combined. The centred quantities produced by Step 0—which may be positive or negative—are therefore never averaged across stages.

In this way the multi-stage competition requires no new statistical rule. It requires only a preliminary construction of the score matrix X . Once that matrix has been formed, everything described in Sections 4–9 applies without modification.

The calculations in Sections 8 and 9 were deliberately stage-by-stage: their purpose was to examine how the one-matrix procedure affects the scores and the ordering expressed by individual jurors. Once the multi-stage construction has been specified, a different practical question can be asked: what overall competition ranking would result if the complete cumulative procedure were used?

We answer this question retrospectively in Appendix G. For each successive stage, Tables G.1–G.4 compare the ranking obtained from the official scoring procedure with the ranking produced by the cumulative procedure defined above. The two methods produce scores on different numerical scales, so their numerical values are not compared directly; the meaningful comparison is between the resulting rankings.

The entire construction is summarized in Figure 1. The diagram should be read from top to bottom. First, the original scores from the relevant stages are combined, with the prescribed stage weights, to form the single input matrix X . Step 0 then acts down the columns of X and produces the calibrated matrix Z . Step 1 acts across the rows of Z , separately for each competitor. The converged row means finally determine the ranking. Thus the diagram introduces no additional rule: it displays in one picture the construction of X described in this section followed by the two operations already defined in Sections 4 and 5.

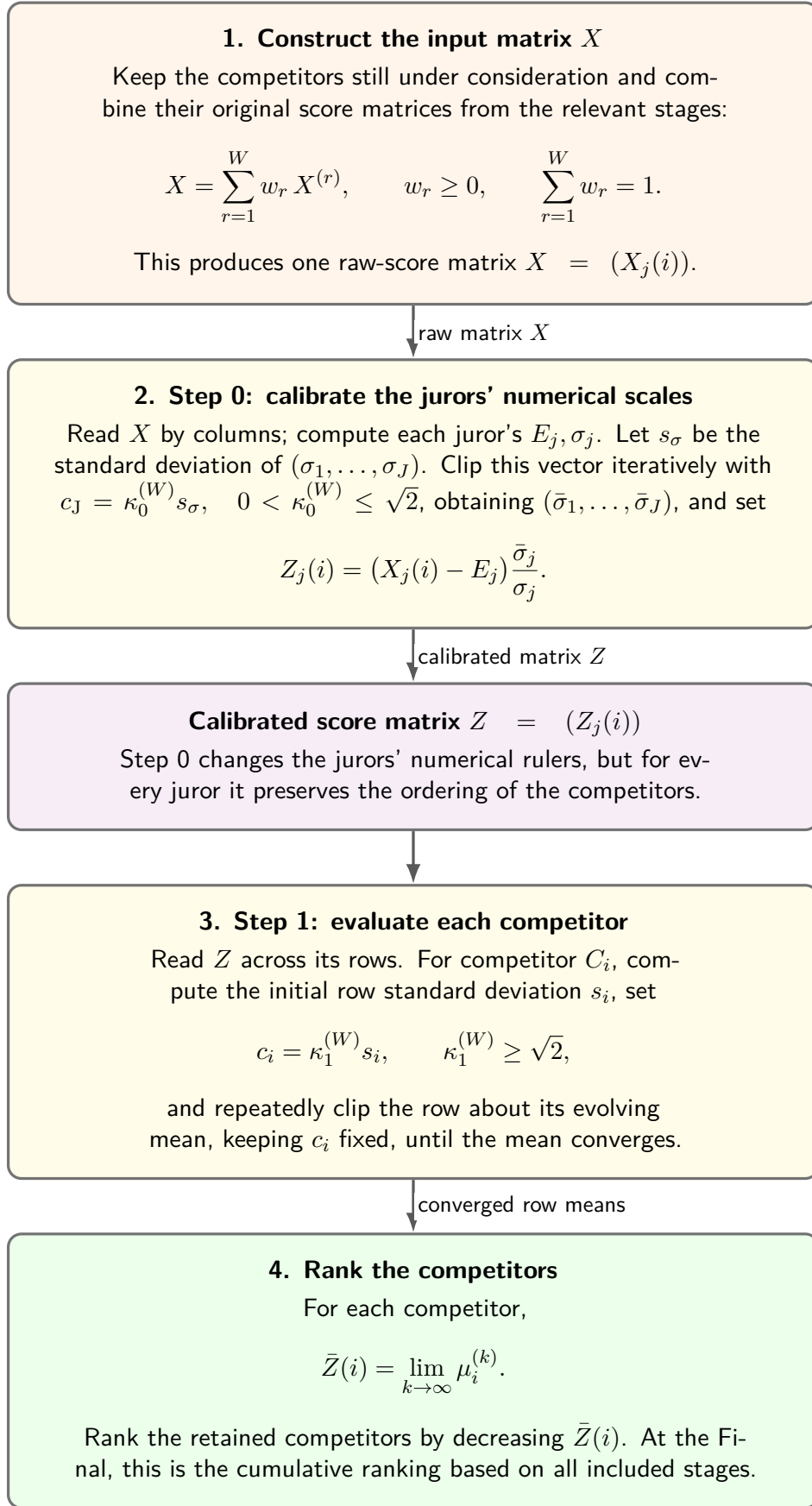


Figure 1: The complete multi-stage scoring procedure. The original scores from the relevant stages are first combined, with the prescribed stage weights, into the single input matrix X . Step 0 calibrates the juror columns, producing Z ; Step 1 then evaluates the competitor rows. The converged row means determine the cumulative ranking at the stage under consideration, denoted by W .

11 Conclusions

The problem studied in this article begins only after the jurors have made their artistic judgements. We do not propose a rule for how a performance should be heard or valued. We address the later numerical question: once the jurors have entered scores, how should those scores be combined?

The score table has two directions, and they answer different questions. Reading down a column shows how one juror uses the numerical scale across competitors. Reading across a row shows how the jury evaluates one competitor. Our procedure uses these directions in that order. Step 0 calibrates the jurors' numerical scales while preserving every juror's ordering of the competitors. Step 1 then combines the calibrated scores for each competitor by iterative clipping. The convergence theorem in Appendix A shows that this iteration always reaches a limit.

In a competition with several stages, these two steps are preceded by one simple operation. For the competitors still under consideration, the original scores from the relevant stages are first combined with the prescribed stage weights. This produces a single raw-score matrix X . Step 0 and Step 1 are then applied to that matrix exactly as in the single-stage case. Thus the stage weights act on the original scores, before centring, calibration, or clipping; the positive and negative calibrated quantities produced later are never averaged across stages.

The clipping widths are $c_j = \kappa_0^{(r)} s_\sigma$ in Step 0, with $0 < \kappa_0^{(r)} \leq \sqrt{2}$, and $c_i = \kappa_1^{(r)} s_i$ in Step 1, with $\kappa_1^{(r)} \geq \sqrt{2}$. The multipliers may differ between steps and stages. They control how strongly the numerical correction can act and are not prescribed by the convergence theorem. Chebyshev's inequality guarantees that, at the first Step 1 clipping operation, no more than one half of the entries can lie outside the corresponding window. The same guarantee holds in Step 0 when $\kappa_0^{(r)} = \sqrt{2}$.

The four published stage score sheets of the XIX International Chopin Competition provide a stage-by-stage test of the admissible choice $\kappa_0^{(r)} = \kappa_1^{(r)} = \sqrt{2}$, which appears to work well on these data. Depending on the stage, Step 1 modifies about 15–17% of the numerical entries. A modified score, however, need not mean that the juror's ordering has changed. After ties are treated according to the definition in Section 7.1, genuine rank alterations occur in 4.59%, 3.15%, 4.23%, and 1.65% of the valid juror–competitor entries in Stages I, II, III, and the Final, respectively; see Table E.1 on p. 30. Thus the numerical correction is substantially more frequent than a genuine change of the ordering expressed by an individual juror.

We also tested a logarithmic transformation inserted between Steps 0 and 1. It slightly reduces the number of scores subjected to the final clipping, but it increases the number of genuine rank alterations in every stage; see Table F.1 on p. 32. For this reason it is not part of the proposed rule.

A separate retrospective comparison asks what the complete multi-stage procedure would have changed in the overall competition ranking. The results are given in Appendix G. The leading results are stable: the winner is unchanged at every stage, and the top three positions in the Final are unchanged. Most rank changes are small, although near a qualification boundary even a small change can affect which competitors advance. The later-stage comparisons are necessarily conditional on the competitors who actually appeared in those stages, because no later-stage scores exist for a competitor who did not in fact qualify.

The complete procedure therefore has a simple order. In a multi-stage competition, first combine the relevant raw-score matrices using the prescribed stage weights. Then calibrate the jurors' numerical scales from the columns of the resulting matrix, and finally apply convergent rowwise clipping to determine the competitors' scores. In the first stage the preliminary combination is trivial, so the same rule applies from the beginning of the competition to the Final.

The raw score matrices, the worked calculations, and the full juror-by-juror comparisons are reproduced in the appendices so that every numerical statement in the main text can be checked directly. The empirical percentages reported here belong to the XIX Competition data; the convergence theorem itself, and the two-step procedure built upon it, are independent of any particular competition.

A Convergence Theorem for Iterative Clipping

This appendix gives the statement and complete proof of the convergence theorem quoted informally in Section 2. The result is a statement about a finite-dimensional dynamical system and is independent of its application to competition scoring.

Theorem A.1 (Convergence of iterative clipping). *Let $m \geq 1$ and $c > 0$. Let $z^{(0)} = (z_1^{(0)}, \dots, z_m^{(0)}) \in \mathbb{R}^m$. Define*

$$\bar{z}^{(k)} = \frac{1}{m} \sum_{i=1}^m z_i^{(k)}$$

and

$$z_i^{(k+1)} = \begin{cases} \bar{z}^{(k)} + c, & z_i^{(k)} > \bar{z}^{(k)} + c, \\ \bar{z}^{(k)} - c, & z_i^{(k)} < \bar{z}^{(k)} - c, \\ z_i^{(k)}, & |z_i^{(k)} - \bar{z}^{(k)}| \leq c. \end{cases} \quad (\text{A.1})$$

Then the sequence $(z^{(k)})$ converges in $\mathbb{R}^m$ to a stationary vector z^* . More precisely, the centred vectors

$$y^{(k)} = z^{(k)} - \bar{z}^{(k)} \mathbf{1}$$

converge to a vector y^* with zero mean and $|y_i^*| \leq c$, while the sequence of means $(\bar{z}^{(k)})$ is bounded and is either stationary, nondecreasing, or nonincreasing. Consequently

$$z^{(k)} \longrightarrow z^* = y^* + \bar{z}^* \mathbf{1},$$

where $\bar{z}^* = \lim_{k \rightarrow \infty} \bar{z}^{(k)}$, and the limiting vector satisfies the fixed-point condition for the clipping dynamics.

The proof separates the motion relative to the current mean from the motion of the mean itself.

A.1 Setup and notation

We work in the Hilbert space $\mathbb{R}^m$ equipped with the standard inner product

$$\langle x, y \rangle = \sum_{i=1}^m x_i y_i, \quad \|x\| = \sqrt{\langle x, x \rangle}.$$

We denote by

$$H_0 := \{y \in \mathbb{R}^m : \sum_{i=1}^m y_i = 0\},$$

the closed linear subspace of vectors with zero mean. The orthogonal projection $P_{H_0} : \mathbb{R}^m \rightarrow H_0$ is given by

$$P_{H_0}(x) = x - \bar{x} \mathbf{1}, \quad \bar{x} = \frac{1}{m} \sum_{i=1}^m x_i, \quad \mathbf{1} = (1, \dots, 1).$$

Fix $c > 0$ and define the closed convex set

$$A := \{v \in \mathbb{R}^m : |v_i| \leq c \text{ for all } i\}.$$

This is the coordinatewise box of half-width c . It is not a linear subspace. The metric projection $P_A : \mathbb{R}^m \rightarrow A$ is the pointwise clipping map

$$(P_A x)_i := \begin{cases} c, & x_i > c, \\ x_i, & |x_i| \leq c, \\ -c, & x_i < -c. \end{cases}$$

It is uniquely characterized by

$$P_A x \in A, \quad \|x - P_A x\| = \min_{u \in A} \|x - u\|.$$

The metric projection onto the closed convex set $A \subset \mathbb{R}^m$ satisfies the variational characterization [3]

$$p = P_A x \iff p \in A \text{ and } \langle u - p, x - p \rangle \leq 0 \quad \forall u \in A. \quad (\text{A.2})$$

This yields the Pythagorean inequality

$$\|x - u\|^2 \geq \|x - P_A x\|^2 + \|P_A x - u\|^2. \quad (\text{A.3})$$

We denote

$$F := A \cap H_0.$$

This is a nonempty closed convex subset of $\mathbb{R}^m$. We next define the centred clipping operator

$$S := P_{H_0} \circ P_A|_{H_0} : H_0 \rightarrow H_0,$$

and the sequence $(y^{(k)})$ by

$$y^{(k+1)} := S(y^{(k)}), \quad y^{(0)} \in H_0.$$

Finally let T be the uncentered clipping operator

$$(T(z))_i := \begin{cases} \bar{z} + c, & z_i > \bar{z} + c, \\ z_i, & |z_i - \bar{z}| \leq c, \\ \bar{z} - c, & z_i < \bar{z} - c. \end{cases}$$

Thus T replaces all coordinates of z lying outside $\bar{z} \pm c$ by the nearest endpoint of this interval, while leaving the remaining coordinates unchanged. We define the sequence

$$z^{(k+1)} := T(z^{(k)}), \quad z^{(0)} \in \mathbb{R}^m.$$

By setting $y^{(0)} = z^{(0)} - \bar{z}^{(0)} \mathbf{1}$ one easily sees that for every $k \geq 0$,

$$y^{(k)} = z^{(k)} - \bar{z}^{(k)} \mathbf{1}. \quad (\text{A.4})$$

Thus, in order to show the convergence of $z^{(k)}$ we show in the next two subsections separately that $y^{(k)}$ and $\bar{z}^{(k)}$ both converge (see Theorems A.7 and A.12).

A.2 Convergence of $y^{(k)}$

Lemma A.2 (Nonexpansiveness of the centered clipping operator in the Euclidean norm). *The operator S is nonexpansive, that is:*

$$\|S(y) - S(z)\| \leq \|y - z\|, \quad \forall y, z \in H_0.$$

Proof. The scalar clipping function is 1-Lipschitz, hence

$$|(P_A y)_i - (P_A z)_i| \leq |y_i - z_i| \quad \forall i.$$

Squaring both sides gives

$$|(P_A y)_i - (P_A z)_i|^2 \leq |y_i - z_i|^2,$$

and summing over $i = 1, \dots, m$ yields

$$\sum_{i=1}^m |(P_A y)_i - (P_A z)_i|^2 \leq \sum_{i=1}^m |y_i - z_i|^2,$$

that is,

$$\|P_A y - P_A z\|^2 \leq \|y - z\|^2.$$

Next, the orthogonal projection $P_{H_0} : \mathbb{R}^m \rightarrow H_0$ is given by

$$P_{H_0}(v) := v - \bar{v} \mathbf{1}, \quad \bar{v} := \frac{1}{m} \sum_{i=1}^m v_i.$$

Since P_{H_0} is an orthogonal projection, it satisfies

$$\|P_{H_0}(v)\| \leq \|v\| \quad \forall v \in \mathbb{R}^m.$$

Because $S(y) = P_{H_0}(P_A y)$ for every $y \in H_0$, we have

$$\|S(y) - S(z)\| = \|P_{H_0}(P_A y - P_A z)\| \leq \|P_A y - P_A z\| \leq \|y - z\|.$$

This completes the proof. $\square$

Lemma A.3 (Fixed points of S). *The fixed point set of $S := P_{H_0} \circ P_A$ is $\text{Fix}(S) = F$.*

Proof. If $y \in F$, then $|y_i| \leq c$ for all i , hence $P_A(y) = y$, and since $y \in H_0$ we have $\overline{P_A(y)} = \bar{y} = 0$. Therefore

$$S(y) = P_{H_0}(P_A(y)) = P_{H_0}(y) = y,$$

so y is a fixed point of S . Conversely, suppose $S(y) = y$ for some $y \in H_0$. Set $p = P_A(y)$ and $\alpha = \bar{p}$. Then

$$y = P_{H_0}(p) = p - \alpha \mathbf{1},$$

so $p_i - y_i = \alpha$ for every coordinate i . If one coordinate satisfies $|y_i| \leq c$, then $p_i = y_i$ and therefore $\alpha = 0$. If $\alpha > 0$, no coordinate can lie in $[-c, c]$ and no coordinate can be greater than c ; hence every coordinate would satisfy $y_i < -c$, contradicting $y \in H_0$. Similarly, $\alpha < 0$ would force every coordinate to satisfy $y_i > c$, again a contradiction. Thus $\alpha = 0$, so $p = y$. Hence $y \in A \cap H_0 = F$. $\square$

Next we introduce the notion of Fejér monotonicity and a convergence criterion for such sequences [3].

Definition A.4 (Fejér monotonicity). Let $C \subset \mathbb{R}^m$ be a nonempty set. A sequence $(y^{(n)})_{n \in \mathbb{N}}$ in $\mathbb{R}^m$ is called *Fejér monotone with respect to C* if

$$\|y^{(n+1)} - c\| \leq \|y^{(n)} - c\| \quad \text{for all } c \in C \text{ and all } n \in \mathbb{N}.$$

Equivalently, the distance from $y^{(n)}$ to every fixed point of C is nonincreasing.

Theorem A.5 (Characterization of convergence for Fejér monotone sequences [3]). *Let $C \subset \mathbb{R}^m$ be a nonempty closed convex set, and let $(y^{(n)})_{n \in \mathbb{N}}$ be Fejér monotone with respect to C . Define $d_C(y) := \inf_{c \in C} \|y - c\|$. Then the following statements are equivalent:*

1. $(y^{(n)})$ converges to a point in C ;
2. $(y^{(n)})$ possesses a sequential cluster point in C ;
3. $d_C(y^{(n)}) \rightarrow 0$ as $n \rightarrow \infty$.

Next we show that the centred sequence is Fejér monotone with respect to $F = \text{Fix}(S)$.

Lemma A.6 (Fejér monotonicity of the iteration). *Let $F = \text{Fix}(S) = A \cap H_0$ and*

$$y^{(k+1)} := S(y^{(k)}), \quad y^{(0)} \in H_0.$$

Then $(y^{(k)})_{k \geq 0}$ is Fejér monotone with respect to F , i.e.

$$\|y^{(k+1)} - u\| \leq \|y^{(k)} - u\| \quad \forall u \in F, \forall k \geq 0.$$

Proof. Let $u \in F$. By definition of F we have $u \in \text{Fix}(S)$, hence

$$S(u) = u.$$

Since S is nonexpansive, we obtain for every $k \geq 0$:

$$\|y^{(k+1)} - u\| = \|S(y^{(k)}) - S(u)\| \leq \|y^{(k)} - u\|.$$

Thus the distance to u is nonincreasing along the sequence $(y^{(k)})$. $\square$

Theorem A.7 (Convergence of $y^{(k)}$). *Let $H_0 \subset \mathbb{R}^m$, $A \subset \mathbb{R}^m$, $F := A \cap H_0$ and $S := P_{H_0} \circ P_A$ be as above. Let $(y^{(k)})_{k \geq 0} \subset H_0$ be defined by*

$$y^{(k+1)} := S(y^{(k)}), \quad y^{(0)} \in H_0.$$

Then

$$d_F(y^{(k)}) \xrightarrow[k \rightarrow \infty]{} 0.$$

Thus by Theorem A.5 $y^{(k)} \xrightarrow[k \rightarrow \infty]{} y^* \in F$.

Proof. Fix any $u \in F$ and for each k set

$$a^{(k)} := P_A(y^{(k)}).$$

Since A is a closed convex set, the metric projection P_A satisfies the Pythagorean inequality A.3

$$\|y^{(k)} - u\|^2 \geq \|y^{(k)} - a^{(k)}\|^2 + \|a^{(k)} - u\|^2.$$

Since H_0 is a closed linear subspace, P_{H_0} is the orthogonal projection, and we have the exact identity for all $u \in H_0$:

$$\|a^{(k)} - u\|^2 = \|a^{(k)} - y^{(k+1)}\|^2 + \|y^{(k+1)} - u\|^2.$$

Because $u \in F \subset A \cap H_0$, we combine these two relations and obtain

$$\|y^{(k)} - u\|^2 \geq \|y^{(k)} - a^{(k)}\|^2 + \|a^{(k)} - y^{(k+1)}\|^2 + \|y^{(k+1)} - u\|^2. \quad (\text{A.5})$$

In particular,

$$\|y^{(k)} - u\|^2 - \|y^{(k+1)} - u\|^2 \geq \|y^{(k)} - a^{(k)}\|^2 + \|a^{(k)} - y^{(k+1)}\|^2 \geq 0. \quad (\text{A.6})$$

Summing (A.6) from $k = 0$ to $N - 1$ gives

$$\|y^{(0)} - u\|^2 - \|y^{(N)} - u\|^2 \geq \sum_{k=0}^{N-1} \left(\|y^{(k)} - a^{(k)}\|^2 + \|a^{(k)} - y^{(k+1)}\|^2 \right) \geq 0.$$

The left-hand side is bounded above by $\|y^{(0)} - u\|^2$, so letting $N \rightarrow \infty$ yields

$$\sum_{k=0}^{\infty} \|y^{(k)} - a^{(k)}\|^2 < \infty, \quad \sum_{k=0}^{\infty} \|a^{(k)} - y^{(k+1)}\|^2 < \infty.$$

Hence

$$\|y^{(k)} - a^{(k)}\| \xrightarrow[k \rightarrow \infty]{} 0, \quad \|a^{(k)} - y^{(k+1)}\| \xrightarrow[k \rightarrow \infty]{} 0. \quad (\text{A.7})$$

By definition, $a^{(k)} \in A$ and $y^{(k+1)} \in H_0$ for all k . From (A.7) we obtain

$$\text{dist}(y^{(k)}, A) \leq \|y^{(k)} - a^{(k)}\| \longrightarrow 0.$$

The sequence $(y^{(k)})$ is bounded, because it is Fejér monotone with respect to the nonempty set F (and in particular with respect to $0 \in F$). Hence it has a convergent subsequence $y^{(k_\ell)} \rightarrow y^*$. Since every $y^{(k)}$ lies in the closed subspace H_0 , we have $y^* \in H_0$; and since $\text{dist}(y^{(k_\ell)}, A) \rightarrow 0$ and A is closed, we also have $y^* \in A$. Thus $y^* \in F$. Theorem A.5 now implies that the entire sequence converges to a point of F ; in particular,

$$d_F(y^{(k)}) \xrightarrow[k \rightarrow \infty]{} 0.$$

$\square$

A.3 Convergence of the mean $\bar{z}^{(k)}$

We first record a simple uniform bound for the sequence of means.

Lemma A.8 (Uniform boundedness of the mean). *Let $z^{(k)}$ evolve according to the clipping dynamics. Then, for every $k \geq 0$ and every coordinate i ,*

$$\min_j z_j^{(0)} \leq z_i^{(k)} \leq \max_j z_j^{(0)}.$$

In particular,

$$\min_j z_j^{(0)} \leq \bar{z}^{(k)} \leq \max_j z_j^{(0)},$$

so the sequence $(\bar{z}^{(k)})$ is bounded.

Proof. Set $a_k = \min_i z_i^{(k)}$ and $b_k = \max_i z_i^{(k)}$. At the next step, a coordinate outside the clipping interval is moved towards the interval, while every other coordinate is left unchanged. A lower outlier is moved upward and an upper outlier is moved downward, and every new coordinate therefore remains in $[a_k, b_k]$. Hence

$$a_k \leq a_{k+1} \leq b_{k+1} \leq b_k.$$

By induction, every coordinate of every $z^{(k)}$ lies between the minimum and maximum of the initial vector. The same is then true of its arithmetic mean. $\square$

The bound is independent of k and depends only on the initial configuration and the clipping width c . We will track “outliers” (with respect to the mean $\bar{z}^{(k)}$) by the sets

$$A_k := \{i : z_i^{(k)} < \bar{z}^{(k)} - c\}, \quad B_k := \{i : z_i^{(k)} > \bar{z}^{(k)} + c\}.$$

Lemma A.9 (Direction of motion and the outlier sets). *For every $k \geq 0$ the following holds:*

(i) *If $\bar{z}^{(k+1)} > \bar{z}^{(k)}$, then $B_{k+1} = \emptyset$.*

(ii) *If $\bar{z}^{(k+1)} < \bar{z}^{(k)}$, then $A_{k+1} = \emptyset$.*

Proof. (i) Assume $\bar{z}^{(k+1)} > \bar{z}^{(k)}$. By construction, $z_i^{(k+1)} \leq \bar{z}^{(k)} + c$ for all i , so in particular

$$\max_i z_i^{(k+1)} \leq \bar{z}^{(k)} + c.$$

Since $\bar{z}^{(k+1)} > \bar{z}^{(k)}$, we have

$$\bar{z}^{(k)} + c < \bar{z}^{(k+1)} + c.$$

Thus for every i ,

$$z_i^{(k+1)} \leq \bar{z}^{(k)} + c < \bar{z}^{(k+1)} + c,$$

so there is no index with $z_i^{(k+1)} > \bar{z}^{(k+1)} + c$, i.e. $B_{k+1} = \emptyset$.

(ii) The argument is symmetric. Assume $\bar{z}^{(k+1)} < \bar{z}^{(k)}$. Then $z_i^{(k+1)} \geq \bar{z}^{(k)} - c$ for all i , so

$$\min_i z_i^{(k+1)} \geq \bar{z}^{(k)} - c.$$

Since $\bar{z}^{(k+1)} < \bar{z}^{(k)}$, we have

$$\bar{z}^{(k+1)} - c < \bar{z}^{(k)} - c,$$

hence for every i ,

$$z_i^{(k+1)} \geq \bar{z}^{(k)} - c > \bar{z}^{(k+1)} - c.$$

Thus there is no index with $z_i^{(k+1)} < \bar{z}^{(k+1)} - c$, i.e. $A_{k+1} = \emptyset$. $\square$

We now show that, under the clipping dynamics, the sequence of means $(\bar{z}^{(k)})_{k \geq 0}$ is monotone. Define the increments

$$\Delta_k := \bar{z}^{(k+1)} - \bar{z}^{(k)}, \quad k \geq 0.$$

We begin with a simple observation: if at any time $\Delta_k = 0$, then the dynamics stabilizes immediately.

Lemma A.10 (Stationarity after a zero increment). *If $\Delta_k := \bar{z}^{(k+1)} - \bar{z}^{(k)} = 0$ for some k , then*

$$z^{(k+2)} = z^{(k+1)} \quad \text{and} \quad \bar{z}^{(k+2)} = \bar{z}^{(k+1)}.$$

In particular, $\bar{z}^{(j)} = \bar{z}^{(k)}$ for all $j \geq k+1$, i.e. the process is stationary from step $k+1$ onward.

Proof. If $\Delta_k = 0$, then $\bar{z}^{(k+1)} = \bar{z}^{(k)}$. Each coordinate $z_i^{(k+1)}$ satisfies

$$\bar{z}^{(k)} - c \leq z_i^{(k+1)} \leq \bar{z}^{(k)} + c.$$

Since $\bar{z}^{(k+1)} = \bar{z}^{(k)}$, this can be rewritten as

$$\bar{z}^{(k+1)} - c \leq z_i^{(k+1)} \leq \bar{z}^{(k+1)} + c,$$

i.e. every coordinate of $z^{(k+1)}$ already lies inside the clipping interval used at the next step. Therefore, when we form $z^{(k+2)}$ by clipping $z^{(k+1)}$ to this same interval $[\bar{z}^{(k+1)} - c, \bar{z}^{(k+1)} + c]$, nothing changes:

$$z^{(k+2)} = z^{(k+1)}.$$

Taking means gives $\bar{z}^{(k+2)} = \bar{z}^{(k+1)}$. Repeating the same argument for later steps shows that the process is stationary from step $k+1$ onward. $\square$

Lemma A.11 (Exact formula for the mean increment). *Let $\Delta_{k+1} := \bar{z}^{(k+2)} - \bar{z}^{(k+1)}$ be the increment of the mean at step $k+1$. Then*

$$m \Delta_{k+1} = \sum_{i \in A_{k+1}} (\bar{z}^{(k+1)} - c - z_i^{(k+1)}) + \sum_{i \in B_{k+1}} (\bar{z}^{(k+1)} + c - z_i^{(k+1)}),$$

where A_{k+1} and B_{k+1} are the lower and upper outlier sets with respect to the mean $\bar{z}^{(k+1)}$.

Proof. By definition of the mean,

$$m \Delta_{k+1} = m(\bar{z}^{(k+2)} - \bar{z}^{(k+1)}) = \sum_{i=1}^m (z_i^{(k+2)} - z_i^{(k+1)}).$$

We now compute the differences $z_i^{(k+2)} - z_i^{(k+1)}$ using the clipping rule at step $k+1$:

$$z_i^{(k+2)} = \begin{cases} \bar{z}^{(k+1)} - c, & i \in A_{k+1}, \\ z_i^{(k+1)}, & \bar{z}^{(k+1)} - c \leq z_i^{(k+1)} \leq \bar{z}^{(k+1)} + c, \\ \bar{z}^{(k+1)} + c, & i \in B_{k+1}. \end{cases}$$

Subtracting $z_i^{(k+1)}$ gives

$$z_i^{(k+2)} - z_i^{(k+1)} = \begin{cases} \bar{z}^{(k+1)} - c - z_i^{(k+1)}, & i \in A_{k+1}, \\ 0, & i \in C_{k+1}, \\ \bar{z}^{(k+1)} + c - z_i^{(k+1)}, & i \in B_{k+1}, \end{cases}$$

where C_{k+1} denotes the set of non-outlier indices at step $k+1$. Summing over all i and using the partition

$$\{1, \dots, m\} = A_{k+1} \cup C_{k+1} \cup B_{k+1},$$

we obtain

$$m \Delta_{k+1} = \sum_{i \in A_{k+1}} (\bar{z}^{(k+1)} - c - z_i^{(k+1)}) + \sum_{i \in B_{k+1}} (\bar{z}^{(k+1)} + c - z_i^{(k+1)}),$$

since the contribution of C_{k+1} is zero. This proves the lemma. $\square$

Theorem A.12 (Monotonicity of the mean). *Under the clipping dynamics, the sequence of means $(\bar{z}^{(k)})_{k \geq 0}$ is monotone: either it is nondecreasing, or it is nonincreasing. Since $\bar{z}^{(k)}$ is bounded, it follows that $\bar{z}^{(k)}$ converges.*

Proof. If $\Delta_0 = 0$, then by Lemma A.10 the trajectory is stationary from step 1 onward, and $(\bar{z}^{(k)})$ is constant, hence trivially monotone. Thus we may assume $\Delta_0 \neq 0$ and distinguish two cases according to the sign of Δ_0 .

Case 1: $\Delta_0 > 0$ (the mean moves upward initially).

We first note that $\Delta_0 > 0$ implies $\bar{z}^{(1)} > \bar{z}^{(0)}$, so by Lemma A.9(i) we have $B_1 = \emptyset$.

We claim that $\Delta_k \geq 0$ for all $k \geq 0$, which implies that $(\bar{z}^{(k)})$ is nondecreasing. We proceed by induction on k .

For $k = 0$ we have $\Delta_0 > 0$ by assumption. Assume now $\Delta_k \geq 0$ for some $k \geq 0$.

If $\Delta_k = 0$, then by Lemma A.10 the process is stationary from step $k + 1$ onward, hence $\Delta_{k+1} = 0$ and in particular $\Delta_{k+1} \geq 0$.

Suppose instead that $\Delta_k > 0$. Then $\bar{z}^{(k+1)} > \bar{z}^{(k)}$, and Lemma A.9(i) gives $B_{k+1} = \emptyset$. By Lemma A.11 the increment Δ_{k+1} can be written as

$$m \Delta_{k+1} = \sum_{i \in A_{k+1}} (\bar{z}^{(k+1)} - c - z_i^{(k+1)}) + \sum_{i \in B_{k+1}} (\bar{z}^{(k+1)} + c - z_i^{(k+1)}).$$

Since $B_{k+1} = \emptyset$, this reduces to

$$m \Delta_{k+1} = \sum_{i \in A_{k+1}} (\bar{z}^{(k+1)} - c - z_i^{(k+1)}).$$

For every $i \in A_{k+1}$ we have $z_i^{(k+1)} < \bar{z}^{(k+1)} - c$, so each summand is strictly positive. If $A_{k+1} = \emptyset$, then the sum is 0; if $A_{k+1} \neq \emptyset$, the sum is strictly positive. In either case $m \Delta_{k+1} \geq 0$, hence $\Delta_{k+1} \geq 0$.

This completes the induction and shows that $(\bar{z}^{(k)})$ is nondecreasing in Case 1.

Case 2: $\Delta_0 < 0$ (the mean moves downward initially).

The argument is symmetric. Since $\Delta_0 < 0$, we have $\bar{z}^{(1)} < \bar{z}^{(0)}$, and Lemma A.9(ii) gives $A_1 = \emptyset$.

We claim that $\Delta_k \leq 0$ for all $k \geq 0$, which implies that $(\bar{z}^{(k)})$ is nonincreasing. Again we argue by induction.

For $k = 0$ we have $\Delta_0 < 0$ by assumption. Suppose $\Delta_k \leq 0$ for some $k \geq 0$.

If $\Delta_k = 0$, then Lemma A.10 implies $\Delta_{k+1} = 0$, so $\Delta_{k+1} \leq 0$.

If $\Delta_k < 0$, then $\bar{z}^{(k+1)} < \bar{z}^{(k)}$, and by Lemma A.9(ii) we have $A_{k+1} = \emptyset$. Hence

$$m \Delta_{k+1} = \sum_{i \in B_{k+1}} (\bar{z}^{(k+1)} + c - z_i^{(k+1)}),$$

and for each $i \in B_{k+1}$ we have $z_i^{(k+1)} > \bar{z}^{(k+1)} + c$, so every summand is strictly negative. If $B_{k+1} = \emptyset$ the sum is zero; otherwise it is negative. In all cases $m \Delta_{k+1} \leq 0$, so $\Delta_{k+1} \leq 0$.

Thus $(\bar{z}^{(k)})$ is nonincreasing in Case 2.

Combining Cases 1 and 2 with the stationary case ($\Delta_0 = 0$) shows that the sequence $(\bar{z}^{(k)})$ is always monotone under the clipping dynamics. $\square$

A.4 Completion of the proof

Proof of Theorem A.1. By Theorem A.7, the centred vectors converge: $y^{(k)} \rightarrow y^* \in A \cap H_0$. By Theorem A.12, the means converge: $\bar{z}^{(k)} \rightarrow \bar{z}^*$. Using (A.4),

$$z^{(k)} = y^{(k)} + \bar{z}^{(k)} \mathbf{1} \rightarrow y^* + \bar{z}^* \mathbf{1} =: z^*.$$

Because $y^* \in A$, every coordinate of z^* lies in $[\bar{z}^* - c, \bar{z}^* + c]$. Hence a further clipping step leaves z^* unchanged. This proves the theorem. $\square$

B Monte Carlo Study of the Convergence Speed

Theorem A.1 proves that the iteration converges; it does not by itself specify how many steps are needed at a prescribed numerical tolerance. This appendix reproduces the Monte Carlo study used for the practical convergence statements in Section 2.

B.1 Simulation protocol

The experiment consists of $I_{\max} = 10^5$ independent trials. In each trial I :

- a number $K_0^I \in \{0, 1, 2\}$ is drawn, representing the number of jurors who do not score the competitor;
- the number of valid scores is therefore $N_0^I = 17 - K_0^I \in \{15, 16, 17\}$;
- the initial scores

$$z_I(0) = (z_{I1}(0), \dots, z_{IN_0^I}(0))$$

are drawn independently and uniformly from the integer set $\{0, 1, \dots, 25\}$ used in this stress test. The value 0 is included only to enlarge the range of this numerical stress test; it is not a score used in the Competition.

For a chosen fixed clipping width c , the iteration is run exactly as in (A.1). It is stopped when

$$|\bar{z}_I(k+1) - \bar{z}_I(k)| < T. \quad (\text{B.1})$$

The number of clipping steps required to satisfy (B.1) is denoted by λ_I .

B.2 Dependence on the stopping tolerance

First fix $c = 3$ and vary the tolerance. The modal values of the empirical distribution of λ_I are shown in Table B.1.

Table B.1: Modal number of clipping steps for $c = 3$ as the stopping tolerance is tightened. Each entry is based on 10^5 independent trials.

Tolerance T	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}
Modal λ_I	5	7	9	11	13

As the tolerance is decreased by one order of magnitude, the peak shifts by approximately two iterations. The complete histograms are displayed in Figure B.1.

B.3 Dependence on the clipping width

Next fix $T = 10^{-3}$ and compare $c = 1, 2, 3$. Although the empirical distributions are not identical, their modal value remains 7. An additional test with the much wider value $c = 7$ has modal value 5.

Table B.2: Modal number of clipping steps at tolerance $T = 10^{-3}$ for four fixed clipping widths. Each entry is based on 10^5 independent trials.

Clipping width c	1	2	3	7
Modal λ_I	7	7	7	5

These experiments support the practical conclusion used in the main text: at the tolerance 10^{-3} , convergence is ordinarily reached in a number of steps well below ten. Tighter numerical tolerances increase the iteration count in a regular and predictable manner.

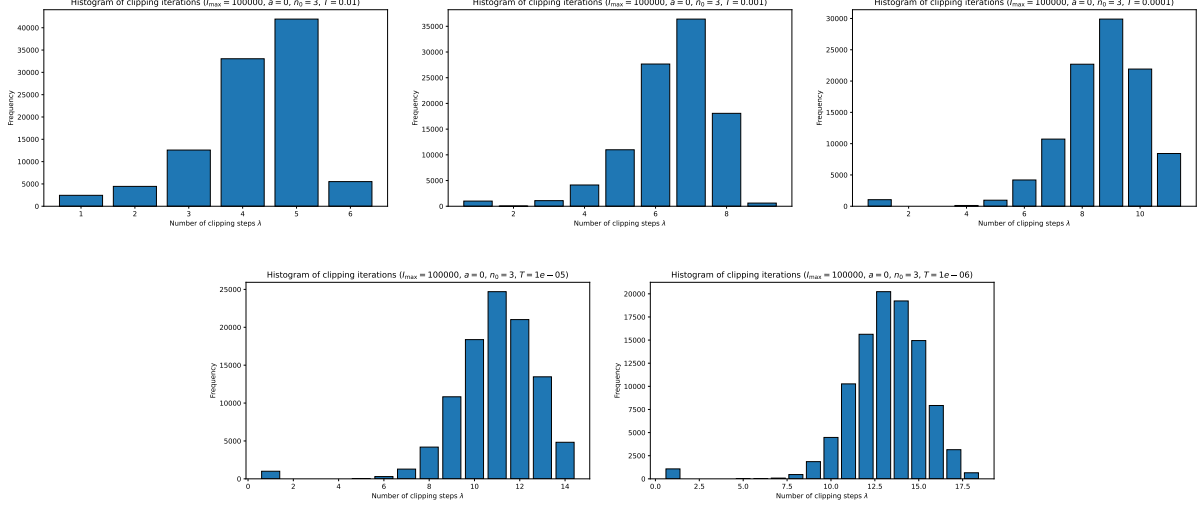


Figure B.1: Empirical distributions of the number of clipping steps λ_I for $c = 3$ and tolerances $10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}$. In every panel $I_{\max} = 10^5$. The isolated bar at one consists of initial vectors for which no clipping is required.

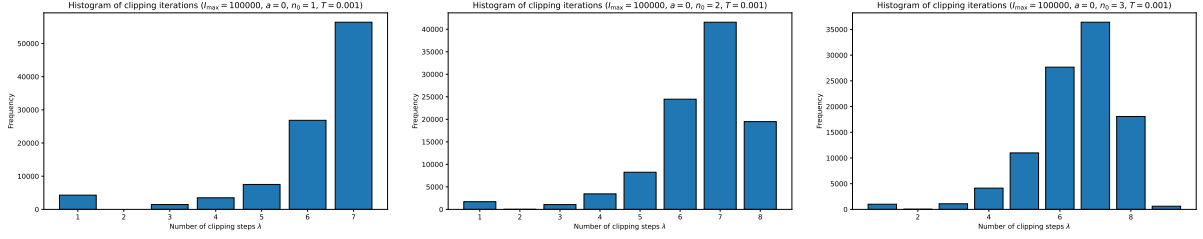


Figure B.2: Empirical distributions of λ_I at $T = 10^{-3}$ for $c = 1, 2, 3$. The peak occurs at seven steps in all three cases.

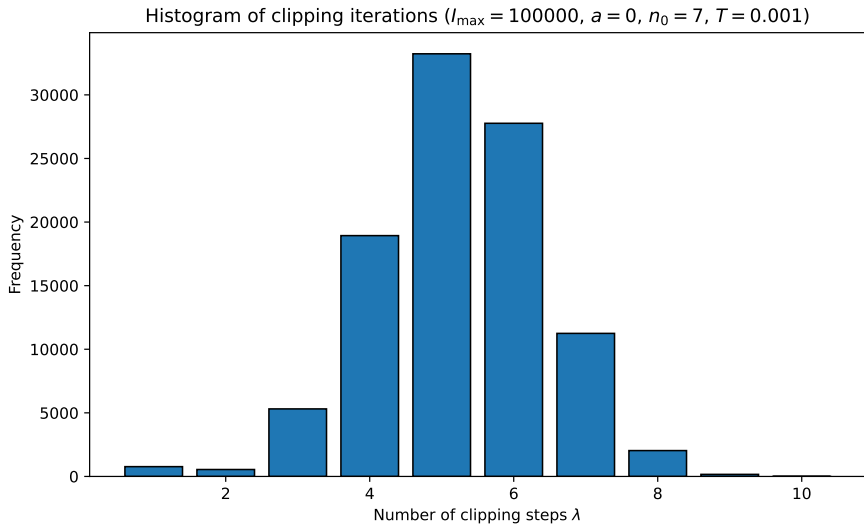


Figure B.3: Empirical distribution of λ_I at $T = 10^{-3}$ for the extended clipping width $c = 7$. The modal value is five steps.

C Official Score Matrices Used in the Empirical Analysis

This appendix reproduces the raw numerical score matrices published by the National Fryderyk Chopin Institute for the four stages of the XIX International Fryderyk Chopin Piano Competition [2]. The rows are competitors, identified by book number and name, and the columns are jurors $J_1, \dots, J_{17}$. The symbol “S” denotes a juror who did not evaluate the corresponding competitor. The final column reproduces the official corrected average printed in the source score sheet. These are the raw data used in the worked examples and in the rank-integrity tables below.

Table C.1: Stage I: official raw score matrix.

Ord.	BN	Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
1	1	Ziye Tao	14	17	19	21	21	S	18	16	17	20	21	21	18	21	18	16	15	18.41
2	2	Chun Lam U	9	14	18	16	17	S	16	17	16	15	17	16	16	19	16	15	12	15.79
3	3	Tomoharu Ushida	19	16	20	19	22	21	24	24	20	19	22	24	S	22	23	19	18	20.81
4	4	Ryan Wang	17	19	19	17	21	16	18	18	15	17	17	15	16	15	17	18	16	17.07
5	5	Zitong Wang	22	21	21	17	22	S	22	17	16	23	23	21	19	23	22	22	22	21.03
6	6	Jan Widlarz	19	16	20	17	20	17	17	17	16	19	20	18	21	21	S	18	20	18.50
7	7	Andrzej Wierciński	17	18	21	24	20	18	21	16	16	15	21	20	21	17	19	21	S	19.02
8	8	Krzysztof Wierciński	18	12	19	17	22	19	21	17	16	20	19	18	22	17	18	18	18	18.40
9	9	Victoria Wong	18	18	20	17	22	17	18	17	15	S	18	19	20	20	18	19	17	18.29
10	10	Maiqi Wu	20	15	19	19	21	19	17	18	19	19	18	17	19	S	21	17	20	18.66
11	11	Yifan Wu	20	20	19	24	23	20	23	24	19	20	24	20	21	22	21	22	23	21.47
12	12	Miki Yamagata	20	13	18	22	21	17	22	20	19	23	23	22	19	17	18	18	19	19.61
13	13	Ryota Yamazaki	19	13	20	16	21	17	21	20	16	16	21	16	18	16	17	16	15	17.54
14	14	Fanze Yang	19	10	20	18	21	21	22	20	16	19	18	23	19	21	19	16	16	18.95
15	15	William Yang	19	21	18	17	20	22	24	22	21	20	18	S	18	21	20	23	20	20.22
16	16	Yuanfan Yang	17	22	20	18	20	17	17	19	20	17	18	16	20	17	19	16	20	18.38
17	17	Yichen Yu	17	22	18	17	21	16	17	20	22	22	20	16	21	18	21	16	16	18.79
18	18	Yuewen Yu	23	17	20	16	21	16	17	15	16	16	19	19	19	21	24	23	16	18.46
19	19	Andrey Zenin	21	22	21	19	22	15	19	14	12	15	18	18	21	15	19	16	15	17.78
20	20	Jacky Zhang	15	17	21	25	24	17	23	20	16	19	20	24	23	24	20	20	22	20.75
21	21	Yonghuan Zhong	16	20	18	15	21	18	17	16	16	16	21	16	21	15	17	16	S	17.33
22	22	Hanyuan Zhu	15	16	18	15	22	S	24	17	16	23	22	20	18	21	21	16	16	18.59
23	23	Jingting Zhu	15	18	19	17	20	16	17	18	21	18	20	S	19	20	20	19	16	18.33
24	24	Piotr Alexewicz	15	22	21	19	21	21	24	24	18	18	24	20	23	22	19	24	20	21.02
25	25	Jonas Aumiller	15	23	20	18	23	22	21	21	19	17	23	22	22	22	20	20	17	20.46
26	26	Yanyan Bao	22	13	22	19	23	22	21	16	16	21	18	23	23	22	19	17	23	20.35
27	27	Michał Basista	22	15	21	17	21	17	17	17	15	18	18	19	18	16	18	16	20	17.87
28	28	Kai-Min Chang	22	17	20	18	23	S	19	17	17	21	20	19	17	21	24	19	21	19.59
29	29	Kevin Chen	20	23	22	25	24	18	25	23	24	24	24	24	22	22	21	22	25	22.93
30	30	Xuehong Chen	19	18	21	19	21	17	21	22	19	24	19	23	23	20	21	19	21	20.40
31	31	Zixi Chen	23	18	23	18	21	18	20	21	17	20	21	19	20	21	23	22	19	20.25
32	32	Hoi Leong Cheong	22	13	19	17	22	20	22	17	17	22	18	S	19	22	22	18	17	19.39
33	33	Diana Cooper	22	17	20	19	20	22	21	15	16	18	19	16	19	16	19	20	19	18.71
34	34	Athena Deng	23	13	20	17	19	S	23	16	16	17	17	18	18	17	18	18	17	17.80
35	35	Yubo Deng	19	18	20	18	22	S	17	23	16	19	19	20	22	22	23	21	15	19.72
36	36	Mateusz Dubiel	17	20	20	21	21	18	17	21	15	19	19	16	21	20	20	18	21	19.12
37	37	Yu-Ang Fan	12	15	19	19	22	21	16	16	15	21	18	24	19	17	19	15	15	17.71
38	38	Alberto Ferro	17	15	21	22	21	17	18	22	18	15	23	19	18	17	20	19	20	18.98
39	39	Yang (Jack) Gao	24	17	20	21	21	21	23	23	15	20	19	23	18	19	24	22	16	20.51
40	40	Shuguang Gong	18	13	19	17	21	18	21	18	19	S	19	21	18	16	23	19	21	18.91
41	41	Eric Guo	18	22	24	24	22	22	22	25	18	22	25	22	24	23	23	25	23	22.78
42	42	Wei-Ting Hsieh	14	21	24	21	21	17	22	17	14	19	21	18	17	15	19	21	20	19.02
43	43	Xiaoyu Hu	24	13	25	17	21	24	23	16	15	20	19	16	19	24	24	18	16	19.60

Continued on next page

Table C.1 (continued)

Ord.	BN Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
44	44 Hasan Ignatov	18	16	22	16	22	17	21	21	15	16	19	16	18	20	19	20	19	18.51
45	45 Zihan Jin	22	21	23	20	21	20	20	21	21	23	19	22	18	21	18	19	20	20.53
46	46 Adam Kałduński	22	15	24	23	23	21	25	21	15	21	23	20	23	16	<i>S</i>	23	21	21.44
47	47 David Khrikuli	18	21	23	23	23	24	22	19	15	19	23	19	18	15	20	23	20	20.52
48	48 Antoni Kleczek	20	14	18	16	21	16	18	20	20	15	19	19	<i>S</i>	<i>S</i>	18	13	16	17.64
49	49 Kaito Kobayashi	21	20	20	21	21	18	20	19	12	16	22	22	18	20	17	16	16	18.96
50	50 Mateusz Krzyżowski	22	13	22	19	22	23	22	18	15	17	17	16	23	18	20	16	19	19.03
51	51 Shiori Kuwahara	22	16	25	24	24	22	23	25	16	21	23	20	22	24	23	18	21	22.03
52	52 Shushi Kyomasu	24	15	19	19	20	17	19	19	21	19	21	18	18	20	23	17	20	19.30
53	53 Hyo Lee	23	20	21	24	21	17	24	20	20	19	21	23	23	<i>S</i>	19	22	20	21.13
54	54 Hyuk Lee	20	21	20	25	21	16	22	19	22	22	22	21	22	<i>S</i>	20	23	21	21.13
55	55 Kwanwook Lee	19	18	21	23	21	21	22	18	23	21	19	19	18	21	18	19	17	19.87
56	56 Luwangzi Li	19	17	19	21	24	15	20	17	19	22	18	23	19	17	22	16	17	19.03
57	57 Tianyou Li	21	18	20	20	24	17	21	18	18	22	20	18	18	22	22	20	17	19.69
58	58 Xiaoxuan Li	15	19	20	17	24	21	23	22	17	23	20	<i>S</i>	23	24	19	24	20	20.88
59	59 Zhexiang Li	19	19	21	17	20	23	23	15	19	21	21	21	24	19	16	18	21	19.89
60	60 Hao-Wei Lin	10	10	19	22	21	17	19	14	17	18	19	16	17	19	17	18	15	17.22
61	61 Pedro Lopez Salas	8	9	22	16	20	14	16	12	16	19	18	16	17	16	15	13	12	15.33
62	62 Eric Lu	22	19	23	24	23	<i>S</i>	22	21	17	21	24	<i>S</i>	24	22	18	22	23	21.82
63	63 Philipp Lynov	20	20	23	20	23	20	23	23	20	21	24	19	22	22	19	19	19	21.00
64	64 Tianyao Lyu	20	16	23	22	22	23	23	19	24	23	22	23	24	24	<i>S</i>	19	23	22.06
65	65 Tiankun Ma	19	18	24	25	22	19	18	20	17	20	23	20	18	18	19	16	18	19.45
66	66 Xuanyi Mao	23	20	24	24	20	17	21	18	18	18	17	18	20	15	15	15	16	18.56
67	67 Ruben Micieli	23	17	22	21	24	23	23	19	19	20	19	21	21	15	21	21	19	20.61
68	68 Nathalia Milstein	24	21	22	22	23	18	24	25	16	17	23	21	19	19	21	24	20	21.26
69	69 Yumeka Nakagawa	17	16	21	22	23	17	23	17	17	19	22	24	20	22	21	18	18	19.78
70	70 Yulia Nakashima	17	18	20	17	20	17	19	16	16	15	20	19	18	14	18	16	18	17.56
71	71 Viet Trung Nguyen	17	20	22	18	21	<i>S</i>	18	14	20	<i>S</i>	21	22	19	20	<i>S</i>	20	17	19.37
72	72 Yuya Nishimoto	18	16	21	20	21	16	19	13	20	16	24	20	22	16	18	21	<i>S</i>	18.84
73	73 Vincent Ong	21	11	22	19	24	24	23	24	24	25	24	24	18	23	22	17	21	22.07
74	74 Arisa Onoda	17	14	18	17	21	<i>S</i>	20	13	14	20	19	19	18	18	16	19	17	17.63
75	75 Piotr Pawlak	24	24	25	22	21	17	24	19	12	15	20	23	23	19	19	24	19	20.92
76	76 Yehuda Prokopowicz	24	20	23	23	24	17	21	19	15	19	20	19	23	20	22	22	19	20.73
77	77 Hao Rao	17	15	24	23	21	18	21	25	19	21	20	20	25	23	24	19	24	21.27
78	78 Anthony Ratinov	23	18	23	21	22	16	23	18	19	18	23	<i>S</i>	22	24	23	20	22	21.06
79	79 Zuzanna Sejbuk	18	17	19	16	20	16	17	15	15	17	20	22	21	17	19	14	19	17.72
80	80 Jun Shimada	19	17	21	22	21	19	22	18	16	19	20	22	18	18	20	17	18	19.25
81	81 Miyu Shindo	20	18	21	24	23	23	24	20	18	24	22	22	23	22	22	22	23	21.92
82	82 Mana Shoji	18	16	20	16	21	18	19	16	16	22	21	22	18	18	<i>S</i>	22	20	18.93
83	83 Gabriele Strata	16	20	22	15	19	24	22	19	14	20	19	20	18	22	21	23	20	19.84
84	84 Eva Strejcova	17	21	20	15	21	16	24	16	13	16	20	16	20	15	22	19	18	18.11

Table C.2: Stage II: official raw score matrix.

Ord.	BN Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
1	20 Jacky Zhang	19	19	20	21	20	19	18	18	16	18	18	19	23	19	17	18	19	18.80
2	24 Piotr Alexewicz	19	23	22	22	22	19	23	23	17	17	22	21	21	21	21	21	21	21.08
3	25 Jonas Aumiller	19	20	21	20	21	22	23	22	18	17	21	20	19	19	16	20	18	19.81
4	26 Yanyan Bao	18	18	21	19	23	17	18	18	17	19	16	19	22	17	19	20	22	18.82
5	28 Kai-Min Chang	21	20	20	21	23	<i>S</i>	18	22	19	21	20	20	18	24	20	22	20	20.52
6	29 Kevin Chen	20	22	23	24	24	19	23	23	24	24	23	22	22	20	19	22	24	22.41
7	30 Xuehong Chen	18	19	21	20	21	19	23	19	19	20	17	22	22	17	22	18	21	19.90

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Table C.2 (continued)

Ord.	BN	Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
8	31	Zixi Chen	22	16	21	21	21	17	18	22	19	21	22	21	17	16	18	17	18	19.29
9	35	Yubo Deng	17	15	20	19	22	S	23	22	18	17	19	19	21	21	20	16	16	19.09
10	39	Yang (Jack) Gao	25	17	20	21	24	18	23	24	17	20	23	23	16	24	20	24	18	21.18
11	41	Eric Guo	18	19	22	24	21	18	18	22	20	20	24	21	20	21	18	22	19	20.32
12	43	Xiaoyu Hu	20	20	22	18	21	18	17	17	17	20	18	20	20	22	18	17	17	18.81
13	45	Zihan Jin	21	22	20	18	20	20	17	21	21	22	16	21	16	18	16	18	17	19.14
14	46	Adam Kałduński	21	16	22	21	20	18	20	20	17	18	20	21	21	18	S	22	19	19.72
15	47	David Khrikuli	17	24	23	24	23	22	23	24	19	23	23	18	19	12	19	24	20	21.35
16	51	Shiori Kuwahara	21	20	22	24	23	19	23	22	19	18	23	16	22	24	22	21	20	21.28
17	53	Hyo Lee	22	22	22	20	20	21	23	20	20	20	20	20	23	S	19	19	22	20.79
18	54	Hyuk Lee	17	20	20	25	20	20	22	20	21	21	19	24	22	S	21	21	21	20.79
19	55	Kwanwook Lee	21	17	20	20	22	21	20	18	18	21	17	18	18	17	18	17	17	18.72
20	58	Xiaoxuan Li	22	18	21	23	20	18	21	20	16	23	18	S	22	23	19	19	21	20.30
21	59	Zhexiang Li	19	22	23	21	21	22	23	17	17	19	17	17	19	16	17	19	18	19.08
22	57	Tianyou Li	23	20	23	21	24	18	23	23	24	23	19	22	19	22	20	23	22	21.86
23	62	Eric Lu	24	23	21	24	22	S	24	25	18	22	24	S	22	25	22	25	22	23.03
24	63	Philipp Lynov	19	22	22	18	21	18	17	20	18	17	24	17	18	17	17	20	18	18.71
25	64	Tianyao Lyu	19	17	20	24	21	20	22	21	18	21	20	20	25	24	S	20	22	20.78
26	67	Ruben Micieli	23	17	23	21	21	18	17	21	19	19	21	17	20	15	16	20	17	19.12
27	68	Nathalia Milstein	21	21	20	22	20	17	20	21	16	21	19	20	17	15	16	21	17	19.26
28	69	Yumeka Nakagawa	17	21	20	23	21	23	24	21	17	22	20	20	19	19	15	19	18	19.98
29	73	Vincent Ong	17	16	20	19	23	24	23	24	18	21	25	21	20	24	21	23	20	21.23
30	75	Piotr Pawlak	25	23	22	21	19	19	22	21	17	21	19	19	21	16	20	24	21	20.59
31	76	Yehuda Prokopowicz	23	22	23	22	21	17	18	22	16	22	19	21	21	20	19	19	19	20.36
32	77	Hao Rao	16	18	22	20	21	17	17	24	17	19	17	22	22	21	18	18	19	19.15
33	78	Anthony Ratinov	22	17	21	20	21	18	21	17	19	21	22	S	19	21	20	20	21	20.13
34	81	Miyu Shindo	17	20	20	23	22	20	19	18	18	21	22	19	23	23	22	22	23	20.82
35	83	Gabriele Strata	16	22	22	18	22	23	24	25	17	17	22	21	21	17	17	22	21	20.63
36	3	Tomoharu Ushida	20	19	24	25	22	19	21	21	24	22	21	22	S	22	20	18	19	21.08
37	5	Zitong Wang	22	22	23	21	22	S	21	17	16	24	19	23	18	24	18	21	18	20.69
38	11	Yifan Wu	21	19	21	24	21	17	23	22	18	20	23	20	19	18	18	20	22	20.32
39	12	Miki Yamagata	19	18	21	24	20	17	22	21	17	22	23	21	18	16	21	21	23	20.35
40	15	William Yang	21	16	20	23	24	24	24	16	22	24	22	S	21	25	24	25	21	22.38

Table C.3: Stage III: official raw score matrix.

Ord.	BN	Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
1	39	Yang (Jack) Gao	25	19	20	20	21	17	16	19	17	19	20	21	18	20	22	25	21	19.88
2	41	Eric Guo	17	18	21	23	19	18	22	21	18	19	24	19	19	17	18	22	20	19.54
3	47	David Khrikuli	18	24	22	24	22	20	16	24	21	20	22	20	21	14	19	23	20	20.77
4	51	Shiori Kuwahara	18	21	22	24	22	19	21	24	20	17	23	22	20	22	23	21	22	21.36
5	53	Hyo Lee	21	20	22	21	19	21	24	22	18	22	20	21	22	S	20	19	21	20.79
6	54	Hyuk Lee	17	18	20	24	20	20	23	21	20	19	20	19	21	S	20	19	21	20.03
7	57	Tianyou Li	22	24	23	22	24	19	22	24	21	22	20	20	21	21	22	24	22	21.98
8	58	Xiaoxuan Li	22	19	20	19	19	18	20	20	20	22	20	S	21	22	19	18	19	19.85
9	64	Tianyao Lyu	19	21	21	21	20	19	18	23	22	23	23	22	23	23	S	20	23	21.43
10	73	Vincent Ong	17	18	20	21	21	22	22	23	21	22	24	17	20	20	21	20	19	20.55
11	75	Piotr Pawlak	24	24	20	21	17	19	23	20	18	17	20	18	21	15	17	18	19	19.31
12	76	Yehuda Prokopowicz	23	22	22	18	19	18	18	22	19	18	21	18	22	18	18	19	19	19.49
13	81	Miyu Shindo	19	20	20	23	20	21	22	20	23	23	20	21	23	21	21	20	21	21.06
14	3	Tomoharu Ushida	21	20	21	21	21	19	20	19	22	20	20	23	S	20	23	20	20	20.58
15	5	Zitong Wang	23	23	22	25	22	S	24	23	19	25	23	22	19	24	20	25	23	22.80

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Table C.3 (continued)

Ord.	BN	Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
16	11	Yifan Wu	20	19	20	24	18	17	21	20	20	20	23	20	20	17	19	20	20	19.80
17	15	William Yang	21	19	20	21	21	20	19	18	21	24	21	S	19	19	24	23	23	20.69
18	24	Piotr Alexewicz	18	21	22	24	21	21	23	23	19	21	23	18	19	19	19	21	21	20.74
19	29	Kevin Chen	16	22	22	24	22	23	22	22	25	23	23	23	23	18	21	23	23	22.36
20	62	Eric Lu	23	24	20	23	22	S	25	25	21	24	24	S	22	24	23	24	24	23.29

Table C.4: Final: official raw score matrix.

Ord.	BN	Competitor	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Official av.
1	57	Tianyou Li	18	21	18	21	24	19	17	19	19	18	20	19	18	16	19	20	20	19.09
2	62	Eric Lu	20	22	19	25	20	S	20	24	20	21	23	S	22	22	21	24	20	21.41
3	64	Tianyao Lyu	17	20	17	22	18	20	23	23	24	24	20	21	24	24	S	19	22	21.25
4	73	Vincent Ong	19	18	18	22	24	24	22	25	23	20	25	20	18	21	17	23	19	21.04
5	81	Miyu Shindo	19	20	15	22	19	20	20	20	20	21	20	19	19	18	21	19	21	19.72
6	5	Zitong Wang	19	25	20	21	18	S	20	23	19	19	22	22	21	22	22	20	19	20.64
7	15	William Yang	19	19	16	21	23	20	18	17	22	23	22	S	23	19	23	21	20	20.48
8	24	Piotr Alexewicz	19	22	19	24	19	21	25	22	19	22	23	22	22	18	20	22	23	21.30
9	29	Kevin Chen	19	24	21	25	24	20	19	21	24	21	21	21	23	20	21	21	23	21.58
10	47	David Khrikuli	17	25	17	21	20	23	20	24	21	23	22	20	22	17	18	22	19	20.72
11	51	Shiori Kuwahara	19	21	16	23	20	19	21	22	21	16	24	23	21	21	23	23	21	21.04

D Worked Numerical Tables for Steps 0 and 1

This appendix gives the numerical tables underlying the worked examples in Sections 4 and 5. They are obtained from the official Final-stage score matrix reproduced in Table C.4. The entries are printed to the precision used in the calculation tables. A dash denotes a missing score “S”.

D.1 Final-stage calibration of the jurors’ scales

Table D.1: Juror means, initial dispersions, and stabilized dispersions in the Final-stage Step 0 example. The final column records whether the iterative clipping of the dispersion vector changes the corresponding juror’s scale width.

Juror	E_j	Initial σ_j	Stabilized $\bar{\sigma}_j$	Modified?
J_1	18.64	0.8814	1.2756	Yes
J_2	21.55	2.2305	2.2305	No
J_3	17.82	1.7487	1.7487	No
J_4	22.45	1.4993	1.4993	No
J_5	20.82	2.3284	2.3284	No
J_6	20.67	1.6330	1.6330	No
J_7	20.45	2.1475	2.1475	No
J_8	21.82	2.2890	2.2890	No
J_9	21.09	1.8318	1.8318	No
J_{10}	20.73	2.2600	2.2600	No
J_{11}	22.00	1.5954	1.5954	No
J_{12}	20.78	1.3147	1.3147	No
J_{13}	21.18	1.9455	1.9455	No
J_{14}	19.82	2.3284	2.3284	No
J_{15}	20.50	1.9105	1.9105	No
J_{16}	21.27	1.6006	1.6006	No
J_{17}	20.64	1.4316	1.4316	No

For this vector of seventeen dispersions, the population standard deviation is $s_\sigma = 0.4028$. With the retrospective choice $\kappa_0^{(r)} = \sqrt{2}$, so that $c_J = \sqrt{2} s_\sigma$, the reported converged centre is 1.8453 and the limiting clipping interval is [1.2756, 2.4150]. Thus only J_1 , whose initial dispersion is 0.8814, is changed; its stabilized value is 1.2756.

Table D.2: Initial and stabilized vectors in the Final-stage Step 0 example.

	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}
$\sigma^{(0)}$	0.8814	2.2305	1.7487	1.4993	2.3284	1.6330	2.1475	2.2890	1.8318	2.2600	1.5954	1.3147	1.9455	2.3284	1.9105	1.6006	1.4316
$\bar{\sigma}$	1.2756	2.2305	1.7487	1.4993	2.3284	1.6330	2.1475	2.2890	1.8318	2.2600	1.5954	1.3147	1.9455	2.3284	1.9105	1.6006	1.4316

Table D.3: Calibrated Final-stage score matrix after Step 0. These are the values $Z_j(i)$ to which Step 1 is applied row by row.

BN	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}
57	-0.9210	-0.5455	0.1818	-1.4545	3.1818	-1.6667	-3.4545	-2.8182	-2.0909	-2.7273	-2.0000	-1.7778	-3.1818	-3.8182	-1.5000	-1.2727	-0.6364
62	1.9735	0.4545	1.1818	2.5455	-0.8182	—	-0.4545	2.1818	-1.0909	0.2727	1.0000	—	0.8182	2.1818	0.5000	2.7273	-0.6364
64	-2.3683	-1.5455	-0.8182	-0.4545	-2.8182	-0.6667	2.5455	1.1818	2.9091	3.2727	-2.0000	0.2222	2.8182	4.1818	—	-2.2727	1.3636
73	0.5263	-3.5455	0.1818	-0.4545	3.1818	3.3333	1.5455	3.1818	1.9091	-0.7273	3.0000	-0.7778	-3.1818	1.1818	-3.5000	1.7273	-1.6364
81	0.5263	-1.5455	-2.8182	-0.4545	-1.8182	-0.6667	-0.4545	-1.8182	-1.0909	0.2727	-2.0000	-1.7778	-2.1818	-1.8182	0.5000	-2.2727	0.3636
5	0.5263	3.4545	2.1818	-1.4545	-2.8182	—	-0.4545	1.1818	-2.0909	-1.7273	0.0000	1.2222	-0.1818	2.1818	1.5000	-1.2727	-1.6364
15	0.5263	-2.5455	-1.8182	-1.4545	2.1818	-0.6667	-2.4545	-4.8182	0.9091	2.2727	0.0000	—	1.8182	-0.8182	2.5000	-0.2727	-0.6364
24	0.5263	0.4545	1.1818	1.5455	-1.8182	0.3333	4.5455	0.1818	-2.0909	1.2727	1.0000	1.2222	0.8182	-1.8182	-0.5000	0.7273	2.3636
29	0.5263	2.4545	3.1818	2.5455	3.1818	-0.6667	-1.4545	-0.8182	2.9091	0.2727	-1.0000	0.2222	1.8182	0.1818	0.5000	-0.2727	2.3636
47	-2.3683	3.4545	-0.8182	-1.4545	-0.8182	2.3333	-0.4545	2.1818	-0.0909	2.2727	0.0000	-0.7778	0.8182	-2.8182	-2.5000	0.7273	-1.6364
51	0.5263	-0.5455	-1.8182	0.5455	-0.8182	-1.6667	0.5455	0.1818	-0.0909	-4.7273	2.0000	2.2222	-0.1818	1.1818	2.5000	1.7273	0.3636

D.2 The complete Step 1 calculation for Book Number 62

For Book Number 62, the initial standard deviation of the calibrated row is 1.2224. The two scores identified as lying outside the Step 1 window are those of J_9 and J_{16} . The converged row mean is 0.8612.

Table D.4: Raw, calibrated, and final Step 1 scores for Book Number 62.

Juror	Raw Score	Calibrated $Z_j(62)$	Final $\hat{Z}_j(62)$	Modified?
J_1	20.0000	1.9735	1.9735	No
J_2	22.0000	0.4545	0.4545	No
J_3	19.0000	1.1818	1.1818	No
J_4	25.0000	2.5455	2.5455	No
J_5	20.0000	-0.8182	-0.8182	No
J_6	—	—	—	—
J_7	20.0000	-0.4545	-0.4545	No
J_8	24.0000	2.1818	2.1818	No
J_9	20.0000	-1.0909	-0.8676	Yes
J_{10}	21.0000	0.2727	0.2727	No
J_{11}	23.0000	1.0000	1.0000	No
J_{12}	—	—	—	—
J_{13}	22.0000	0.8182	0.8182	No
J_{14}	22.0000	2.1818	2.1818	No
J_{15}	21.0000	0.5000	0.5000	No
J_{16}	24.0000	2.7273	2.5846	Yes
J_{17}	20.0000	-0.6364	-0.6364	No

Table D.5: Final-stage score matrix after Step 1. Bold entries were modified by rowwise clipping. The last column is the converged mean of the corresponding row.

BN	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}	J_{17}	Final score
57	-0.9210	-0.5455	0.1818	-1.4545	0.5274	-1.6667	-3.4545	-2.8182	-2.0910	-2.7273	-2.0000	-1.7778	-3.1818	-3.8000	-1.5000	-1.2727	-0.6364	-1.7140
62	1.9735	0.4545	1.1818	2.5455	-0.8182	—	-0.4545	2.1818	-0.8676	0.2727	1.0000	—	0.8182	2.1818	0.5000	2.5846	-0.6364	0.8612
64	-2.3683	-1.5455	-0.8182	-0.4545	-2.7933	-0.6667	2.5455	1.1818	2.9091	3.2727	-2.0000	0.2222	2.8182	3.4425	—	-2.2727	1.3636	0.3023
73	0.5263	-2.7511	0.1818	-0.4545	3.1818	3.3333	1.5455	3.1818	1.9091	-0.7273	3.0000	-0.7778	-2.7511	1.1818	-2.7510	1.7273	-1.6364	0.4658
81	0.3587	-1.5455	-2.6064	-0.4545	-1.8182	-0.6667	-0.4545	-1.8182	-1.0910	0.2727	-2.0000	-1.7778	-2.1818	-1.8182	0.3587	-2.2727	0.3587	-1.1269
5	0.5263	2.4707	2.1818	-1.4545	-2.4315	—	-0.4545	1.1818	-2.0910	-1.7273	0.0000	1.2222	-0.1818	2.1818	1.5000	-1.2727	-1.6364	0.0009
15	0.5263	-2.5455	-1.8182	-1.4545	2.1818	-0.6667	-2.4545	-2.9936	0.9091	2.2727	0.0000	—	1.8182	-0.8182	2.4446	-0.2727	-0.6364	-0.2192
24	0.5263	0.4545	1.1818	1.5455	-1.6216	0.3333	2.7359	0.1818	-1.6220	1.2727	1.0000	1.2222	0.8182	-1.6220	-0.5000	0.7273	2.3636	0.5293
29	0.5263	2.4545	3.1110	2.5455	3.1110	-0.6667	-1.2302	-0.8182	2.9091	0.2727	-1.0000	0.2222	1.8182	0.1818	0.5000	-0.2727	2.3636	0.9428
47	-2.3683	2.3757	-0.8182	-1.4545	-0.8182	2.3333	-0.4545	2.1818	-0.0910	2.2727	0.0000	-0.7778	0.8182	-2.6590	-2.5000	0.7273	-1.6364	-0.1688
51	0.5263	-0.5455	-1.8182	0.5455	-0.8182	-1.6667	0.5455	0.1818	-0.0910	-2.1553	2.0000	2.2222	-0.1818	1.1818	2.5000	1.7273	0.3636	0.2657

E Complete Rank-Integrity Tables

The tables in this appendix give the calculations underlying Section 8, starting from the official stage matrices reproduced in Tables C.1–C.4. For each juror, “scores clipped” is the number of entries modified by Step 1, while “genuine alterations” applies the tie-aware definition of Section 7.1. The alteration rate is the number of genuine alterations divided by the number of valid scores given by that juror.

Table E.1: Aggregate rank-integrity results for the four stages.

Stage	Valid Scores	Scores Clipped	Clipped Rate	Genuine Alterations	Alteration Rate
I	1395	215	15.41%	64	4.59%
II	667	115	17.24%	21	3.15%
III	331	54	16.31%	14	4.23%
Final	182	27	14.84%	3	1.65%

Table E.2: Juror-by-juror rank-integrity results for Stage I.

Juror	Scores Clipped	Genuine Alterations	Valid Scores	Rate
J_1	26	9	84	10.71%
J_2	27	12	84	14.29%
J_3	7	3	84	3.57%
J_4	18	6	84	7.14%
J_5	3	0	84	0.00%
J_6	15	6	74	8.11%
J_7	8	2	84	2.38%
J_8	19	5	84	5.95%
J_9	16	6	84	7.14%
J_{10}	12	4	81	4.94%
J_{11}	4	0	84	0.00%
J_{12}	13	3	78	3.85%
J_{13}	8	0	82	0.00%
J_{14}	11	4	80	5.00%
J_{15}	10	3	79	3.80%
J_{16}	12	1	84	1.19%
J_{17}	6	0	81	0.00%
Overall	215	64	1395	4.59%

Table E.3: Juror-by-juror rank-integrity results for Stage II.

Juror	Scores Clipped	Genuine Alterations	Valid Scores	Rate
J_1	13	2	40	5.00%
J_2	13	3	40	7.50%
J_3	3	0	40	0.00%
J_4	4	0	40	0.00%
J_5	3	0	40	0.00%
J_6	8	1	36	2.78%
J_7	10	1	40	2.50%
J_8	8	5	40	12.50%
J_9	8	0	40	0.00%
J_{10}	6	1	40	2.50%
J_{11}	8	2	40	5.00%
J_{12}	2	1	36	2.78%
J_{13}	7	2	39	5.13%
J_{14}	10	3	38	7.89%
J_{15}	3	0	38	0.00%
J_{16}	4	0	40	0.00%
J_{17}	5	0	40	0.00%
Overall	115	21	667	3.15%

Table E.4: Juror-by-juror rank-integrity results for Stage III.

Juror	Scores Clipped	Genuine Alterations	Valid Scores	Rate
J_1	9	4	20	20.00%
J_2	5	1	20	5.00%
J_3	1	1	20	5.00%
J_4	4	1	20	5.00%
J_5	1	0	20	0.00%
J_6	1	0	18	0.00%
J_7	7	1	20	5.00%
J_8	2	0	20	0.00%
J_9	4	0	20	0.00%
J_{10}	2	1	20	5.00%
J_{11}	4	1	20	5.00%
J_{12}	3	0	17	0.00%
J_{13}	2	1	19	5.26%
J_{14}	4	2	18	11.11%
J_{15}	2	0	19	0.00%
J_{16}	3	1	20	5.00%
J_{17}	0	0	20	0.00%
Overall	54	14	331	4.23%

Table E.5: Juror-by-juror rank-integrity results for the Final.

Juror	Scores Clipped	Genuine Alterations	Valid Scores	Rate
J_1	1	0	11	0.00%
J_2	3	1	11	9.09%
J_3	2	0	11	0.00%
J_4	0	0	11	0.00%
J_5	5	1	11	9.09%
J_6	0	0	9	0.00%
J_7	2	0	11	0.00%
J_8	1	0	11	0.00%
J_9	2	0	11	0.00%
J_{10}	1	1	11	9.09%
J_{11}	0	0	11	0.00%
J_{12}	0	0	9	0.00%
J_{13}	1	0	11	0.00%
J_{14}	4	0	11	0.00%
J_{15}	3	0	10	0.00%
J_{16}	1	0	11	0.00%
J_{17}	1	0	11	0.00%
Overall	27	3	182	1.65%

E.1 The three tie groups in the Final-stage column of J_5

Table E.6: The three-way tie for first place in the Final-stage scores of J_5 . Book Number 57 leaves the original tie range $[1, 3]$ and is counted as a genuine alteration; Book Numbers 73 and 29 remain within it.

BN	Raw Score	Raw Rank	Calibrated Score	Step 1 Score	Final Rank	Genuine Alteration?
57	24	1	3.1818	0.5274	4	Yes
73	24	1	3.1818	3.1818	1	No
29	24	1	3.1818	3.1110	2	No
15	23	4	2.1818	2.1818	3	No

Table E.7: The tie occupying positions $[8, 9]$ in the Final-stage scores of J_5 . Both competitors remain within the original tie range.

BN	Raw Score	Raw Rank	Calibrated Score	Step 1 Score	Final Rank	Genuine Alteration?
81	19	8	-1.8182	-1.8182	9	No
24	19	8	-1.8182	-1.6216	8	No

Table E.8: The tie occupying positions $[10, 11]$ in the Final-stage scores of J_5 . Both competitors remain within the original tie range.

BN	Raw Score	Raw Rank	Calibrated Score	Step 1 Score	Final Rank	Genuine Alteration?
64	18	10	-2.8182	-2.7933	11	No
5	18	10	-2.8182	-2.4315	10	No

F Complete Linear–Logarithmic Comparison

This appendix gives the data underlying Section 9. Both variants are applied to the same official score matrices reproduced in Tables C.1–C.4. “Linear” denotes the procedure in which Step 0 is followed directly by Step 1. “With log” denotes the alternative in which the logarithmic transformation is inserted between those two steps. In both cases the same definition of genuine rank alteration is used.

Table F.1: Aggregate comparison of the linear procedure and logarithmic dampening.

Stage	Valid	Linear		With log	
		Clipped	Genuine	Clipped	Genuine
I	1395	215	64	214	79
II	667	115	21	100	28
III	331	54	14	52	17
Final	182	27	3	26	4

Table F.2: Stage I: linear procedure versus logarithmic dampening.

Juror	Valid	Linear		With log	
		Clip	Genuine	Clip	Genuine
J_1	84	26	9	28	11
J_2	84	27	12	28	15
J_3	84	7	3	3	3
J_4	84	18	6	18	7
J_5	84	3	0	3	0
J_6	74	15	6	14	6
J_7	84	8	2	8	2
J_8	84	19	5	21	7
J_9	84	16	6	18	8
J_{10}	81	12	4	14	4
J_{11}	84	4	0	6	0
J_{12}	78	13	3	10	3
J_{13}	82	8	0	7	1
J_{14}	80	11	4	9	5
J_{15}	79	10	3	10	5
J_{16}	84	12	1	10	2
J_{17}	81	6	0	7	0
Overall	1395	215	64	214	79

Table F.4: Stage III: linear procedure versus logarithmic dampening.

Juror	Valid	Linear		With log	
		Clip	Genuine	Clip	Genuine
J_1	20	9	4	9	4
J_2	20	5	1	3	1
J_3	20	1	1	1	1
J_4	20	4	1	3	1
J_5	20	1	0	0	0
J_6	18	1	0	2	0
J_7	20	7	1	8	2
J_8	20	2	0	2	0
J_9	20	4	0	4	0
J_{10}	20	2	1	3	1
J_{11}	20	4	1	3	2
J_{12}	17	3	0	3	1
J_{13}	19	2	1	1	1
J_{14}	18	4	2	4	2
J_{15}	19	2	0	3	0
J_{16}	20	3	1	3	1
J_{17}	20	0	0	0	0
Overall	331	54	14	52	17

Table F.3: Stage II: linear procedure versus logarithmic dampening.

Juror	Valid	Linear		With log	
		Clip	Genuine	Clip	Genuine
J_1	40	13	2	15	3
J_2	40	13	3	11	3
J_3	40	3	0	4	0
J_4	40	4	0	3	0
J_5	40	3	0	1	0
J_6	36	8	1	7	3
J_7	40	10	1	9	1
J_8	40	8	5	5	4
J_9	40	8	0	6	0
J_{10}	40	6	1	4	2
J_{11}	40	8	2	7	2
J_{12}	36	2	1	2	1
J_{13}	39	7	2	7	2
J_{14}	38	10	3	10	5
J_{15}	38	3	0	4	0
J_{16}	40	4	0	3	1
J_{17}	40	5	0	2	1
Overall	667	115	21	100	28

Table F.5: Final: linear procedure versus logarithmic dampening.

Juror	Valid	Linear		With log	
		Clip	Genuine	Clip	Genuine
J_1	11	1	0	1	0
J_2	11	3	1	3	2
J_3	11	2	0	0	0
J_4	11	0	0	0	0
J_5	11	5	1	6	1
J_6	9	0	0	0	0
J_7	11	2	0	2	0
J_8	11	1	0	1	0
J_9	11	2	0	2	0
J_{10}	11	1	1	3	1
J_{11}	11	0	0	0	0
J_{12}	9	0	0	0	0
J_{13}	11	1	0	1	0
J_{14}	11	4	0	3	0
J_{15}	10	3	0	3	0
J_{16}	11	1	0	0	0
J_{17}	11	1	0	1	0
Overall	182	27	3	26	4

G Retrospective Comparison of the Official and Proposed Rankings

We now apply the complete cumulative procedure of Section 10 to the published data of the XIX International Chopin Competition. At each stage, the relevant raw score matrices are first combined with the prescribed weights, and Step 0 and Step 1 are then applied to the resulting matrix X . The *official cumulative score* is obtained by combining the corresponding official corrected stage averages with the same prescribed weights. The proposed score is the converged row mean produced by our procedure.

The official and proposed scores are expressed on different numerical scales and should therefore not be compared by magnitude. What can be compared directly are the rankings they produce. We define

$$\text{rank change} = \text{official rank} - \text{proposed rank},$$

so that a positive value denotes an upward movement under the proposed rule.

The same standard competition-ranking convention is used for ties in both the official and proposed rankings. For qualification, the official cutoff ranks are 40 after Stage I, 20 after Stage II, and 10 after Stage III; all competitors tied at the cutoff rank advance.

The resulting official and proposed rankings are shown stage by stage in the four tables below, beginning with Stage I and ending with the Final. In each table, nonzero rank changes are highlighted in bold.

Table G.1: Stage I: official and proposed cumulative rankings.

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
Kevin Chen	22.93	1	3.4948	1	0
Eric Guo	22.78	2	3.2129	2	0
Vincent Ong	22.07	3	2.3841	6	-3
Tianyao Lyu	22.06	4	2.4447	3	+1
Shiori Kuwahara	22.03	5	2.3756	7	-2
Miyu Shindo	21.92	6	2.4031	4	+2
Eric Lu	21.82	7	2.3966	5	+2
Yifan Wu	21.47	8	2.1004	8	0
Adam Kałduński	21.44	9	1.8706	9	0
Hao Rao	21.27	10	1.6341	11	-1
Nathalia Milstein	21.26	11	1.6644	10	+1
Hyo Lee	21.13	12	1.6292	12	0
Hyuk Lee	21.13	12	1.6287	13	-1
Anthony Ratinov	21.06	14	1.6254	14	0
Zitong Wang	21.03	15	1.4197	18	-3
Piotr Alexewicz	21.02	16	1.5205	16	0
Philipp Lynov	21.00	17	1.6046	15	+2
Piotr Pawlak	20.92	18	1.2456	21	-3
Xiaoxuan Li	20.88	19	1.4719	17	+2
Tomoharu Ushida	20.81	20	1.2672	19	+1
Jacky Zhang	20.75	21	1.2600	20	+1
Yehuda Prokopowicz	20.73	22	1.1948	23	-1
Ruben Miceli	20.61	23	1.2242	22	+1
Zihan Jin	20.53	24	1.1158	24	0
David Khrikuli	20.52	25	0.9498	25	0
Yang (Jack) Gao	20.51	26	0.8646	28	-2
Jonas Aumiller	20.46	27	0.8876	27	0
Xuehong Chen	20.40	28	0.8935	26	+2
Yanyan Bao	20.35	29	0.6644	31	-2
Zixi Chen	20.25	30	0.7110	30	0
William Yang	20.22	31	0.7963	29	+2
Zhexiang Li	19.89	32	0.3999	32	0
Kwanwook Lee	19.87	33	0.2495	35	-2
Gabriele Strata	19.84	34	0.1240	39	-5
Yumeka Nakagawa	19.78	35	0.3398	33	+2
Yubo Deng	19.72	36	0.1932	36	0
Tianyou Li	19.69	37	0.3277	34	+3
Miki Yamagata	19.61	38	0.0499	41	-3
Xiaoyu Hu	19.60	39	0.1477	38	+1
Kai-Min Chang	19.59	40	0.1879	37	+3
Tiankun Ma	19.45	41	0.0796	40	+1

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Table G.1 (Stage I, continued)

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
Hoi Leong Cheong	19.39	42	-0.1679	43	-1
Viet Trung Nguyen	19.37	43	-0.1432	42	+1
Shushi Kyomasu	19.30	44	-0.3427	47	-3
Jun Shimada	19.25	45	-0.3183	45	0
Mateusz Dubiel	19.12	46	-0.3262	46	0
Mateusz Krzyżowski	19.03	47	-0.5560	51	-4
Luwangzi Li	19.03	47	-0.3070	44	+3
Wei-Ting Hsieh	19.02	49	-0.5553	50	-1
Andrzej Wierciński	19.02	49	-0.5266	48	+1
Alberto Ferro	18.98	51	-0.5285	49	+2
Kaito Kobayashi	18.96	52	-0.6197	54	-2
Fanze Yang	18.95	53	-0.5870	53	0
Mana Shoji	18.93	54	-0.5664	52	+2
Shuguang Gong	18.91	55	-0.6635	56	-1
Yuya Nishimoto	18.84	56	-0.6328	55	+1
Yichen Yu	18.79	57	-0.8360	60	-3
Diana Cooper	18.71	58	-0.8934	61	-3
Maiqi Wu	18.66	59	-0.8138	58	+1
Hanyuan Zhu	18.59	60	-0.7975	57	+3
Xuanyi Mao	18.56	61	-0.8310	59	+2
Hasan Ignatov	18.51	62	-0.9008	62	0
Jan Widlarz	18.50	63	-0.9534	63	0
Yuewen Yu	18.46	64	-0.9913	64	0
Ziye Tao	18.41	65	-1.1195	66	-1
Krzysztof Wierciński	18.40	66	-1.0726	65	+1
Yuanfan Yang	18.38	67	-1.2861	69	-2
Jingting Zhu	18.33	68	-1.2835	68	0
Victoria Wong	18.29	69	-1.1554	67	+2
Eva Strejcova	18.11	70	-1.4388	70	0
Michał Basista	17.87	71	-1.6918	72	-1
Athena Deng	17.80	72	-1.8870	76	-4
Andrey Zenin	17.78	73	-1.8374	74	-1
Zuzanna Sejbuk	17.72	74	-1.7622	73	+1
Yu-Ang Fan	17.71	75	-1.6483	71	+4
Antoni Kłeczek	17.64	76	-1.9261	78	-2
Arisa Onoda	17.63	77	-1.9233	77	0
Yulia Nakashima	17.56	78	-1.8636	75	+3
Ryota Yamazaki	17.54	79	-1.9852	79	0
Yonghuan Zhong	17.33	80	-2.2054	80	0
Hao-Wei Lin	17.22	81	-2.3388	81	0
Ryan Wang	17.07	82	-2.4329	82	0
Chun Lam U	15.79	83	-3.8820	83	0
Pedro Lopez Salas	15.33	84	-4.1523	84	0

Table G.2: Stage II: official and proposed cumulative rankings.

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
Eric Lu	22.67	1	2.1620	1	0
Kevin Chen	22.57	2	2.0525	2	0

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Table G.2 (Stage II, continued)

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
William Yang	21.73	3	1.1866	3	0
Shiori Kuwahara	21.51	4	1.0767	4	0
Vincent Ong	21.48	5	0.9894	5	0
Tianyou Li	21.21	6	0.7860	6	0
Tianyao Lyu	21.16	7	0.6798	10	-3
Miyu Shindo	21.15	8	0.7163	9	-1
David Khrikuli	21.10	9	0.7214	8	+1
Piotr Alexewicz	21.06	10	0.5955	12	-2
Eric Guo	21.06	10	0.7401	7	+3
Tomoharu Ushida	21.00	12	0.6505	11	+1
Yang (Jack) Gao	20.98	13	0.4341	15	-2
Hyo Lee	20.89	14	0.5071	13	+1
Hyuk Lee	20.89	14	0.4798	14	0
Zitong Wang	20.79	16	0.2746	16	0
Piotr Pawlak	20.69	17	0.0864	18	-1
Yifan Wu	20.67	18	0.2484	17	+1
Xiaoxuan Li	20.47	19	-0.1018	22	-3
Yehuda Prokopowicz	20.47	19	-0.0078	19	0
Anthony Ratinov	20.41	21	-0.0221	20	+1
Gabriele Strata	20.39	22	-0.1151	23	-1
Kai-Min Chang	20.24	23	-0.0780	21	+2
Adam Kaldunski	20.24	23	-0.2727	24	-1
Miki Yamagata	20.13	25	-0.3435	26	-1
Xuehong Chen	20.05	26	-0.3037	25	+1
Jonas Aumiller	20.01	27	-0.4402	27	0
Yumeka Nakagawa	19.92	28	-0.4701	28	0
Nathalia Milstein	19.86	29	-0.6708	30	-1
Hao Rao	19.79	30	-0.5965	29	+1
Zixi Chen	19.58	31	-0.8804	32	-1
Ruben Micieli	19.57	32	-0.7805	31	+1
Zihan Jin	19.56	33	-0.9443	34	-1
Philipp Lynov	19.40	34	-0.8961	33	+1
Jacky Zhang	19.38	35	-1.1089	37	-2
Zhexiang Li	19.32	36	-0.9647	35	+1
Yanyan Bao	19.28	37	-1.1087	36	+1
Yubo Deng	19.28	37	-1.1904	38	-1
Kwanwook Lee	19.06	39	-1.2870	40	-1
Xiaoyu Hu	19.05	40	-1.2810	39	+1

Table G.3: Stage III: official and proposed cumulative rankings.

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
Eric Lu	23.09	1	2.0532	1	0
Kevin Chen	22.43	2	1.4179	2	0
Zitong Wang	22.20	3	1.1409	3	0
Tianyou Li	21.73	4	0.8503	4	0
Shiori Kuwahara	21.41	5	0.5097	5	0
Tianyao Lyu	21.36	6	0.3665	6	0
Miyu Shindo	21.10	7	0.1996	7	0

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Table G.3 (Stage III, continued)

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
William Yang	20.98	8	0.1305	8	0
David Khrikuli	20.86	9	0.0215	9	0
Piotr Alexewicz	20.84	10	-0.0056	10	0
Vincent Ong	20.84	10	-0.1503	12	-2
Hyo Lee	20.82	12	-0.0869	11	+1
Tomoharu Ushida	20.70	13	-0.2246	13	0
Hyuk Lee	20.29	14	-0.5601	14	0
Yang (Jack) Gao	20.20	15	-0.8443	17	-2
Yifan Wu	20.07	16	-0.8114	16	0
Xiaoxuan Li	20.04	17	-0.9831	18	-1
Eric Guo	20.02	18	-0.7555	15	+3
Yehuda Prokopowicz	19.79	19	-1.0819	19	0
Piotr Pawlak	19.73	20	-1.2291	20	0

Table G.4: Final: official and proposed cumulative rankings.

Competitor	Official cumulative score	Official rank	Proposed score	Proposed rank	Rank change
Eric Lu	22.43	1	1.1917	1	0
Kevin Chen	22.15	2	0.8474	2	0
Zitong Wang	21.45	3	0.2119	3	0
Shiori Kuwahara	21.30	4	0.1053	4	0
Tianyao Lyu	21.30	4	-0.0192	5	-1
Piotr Alexewicz	21.03	6	-0.1754	6	0
Vincent Ong	21.01	7	-0.1834	7	0
William Yang	20.91	8	-0.2237	8	0
David Khrikuli	20.84	9	-0.3483	9	0
Tianyou Li	20.72	10	-0.4786	10	0
Miyu Shindo	20.63	11	-0.5417	11	0

The four tables above give the detailed stage-by-stage comparison. Their overall pattern of rank changes is summarized in Table G.5.

G.1 Summary and comments

Table G.5: Summary of displayed rank changes under the proposed cumulative procedure.

Stage	Competitors	Same rank	Different rank	Within 2 places	Largest absolute change
Stage I	84	28	56	68	5
Stage II	40	11	29	37	3
Stage III	20	15	5	19	3
Final	11	10	1	11	1

The summary above condenses the numerical changes. We now spell out the main consequences for the rankings themselves and for the qualification boundaries.

The winner is unchanged at every stage. Kevin Chen remains first in Stage I, and Eric Lu remains first in Stage II, Stage III, and the Final.

In Stage I, 28 of 84 competitors retain the same displayed rank and 68 remain within two places of their official rank. The largest upward change is +4, for Yu-Ang Fan, and the largest downward change is -5, for Gabriele Strata.

In Stage II, 11 of 40 competitors retain the same displayed rank and 37 remain within two places. The largest upward change is +3, for Eric Guo; the largest downward change is -3, shared by Tianyao Lyu and Xiaoxuan Li.

In Stage III, 15 of 20 displayed ranks are unchanged and 19 competitors remain within two places. The largest upward change is +3, for Eric Guo; the largest downward change is -2, shared by Vincent Ong and Yang (Jack) Gao.

In the Final, 10 of 11 displayed ranks are unchanged. The only change is Tianyao Lyu's move from the official tie at rank 4 to proposed rank 5; thus the winner and the top three positions are unchanged.

For qualification, the official cutoff ranks are 40 after Stage I, 20 after Stage II, and 10 after Stage III; every competitor tied at a cutoff rank advances. The proposed ranking produces a one-for-one exchange at each of the first two boundaries: Tiankun Ma would replace Miki Yamagata after Stage I, and Anthony Ratinov would replace Xiaoxuan Li after Stage II.

The Stage III boundary is different. The official ranking had a tie at rank 10, so eleven pianists advanced to the Final. Under the proposed ranking, Piotr Alexewicz alone occupies rank 10, Hyo Lee is ranked 11, and Vincent Ong is ranked 12. Consequently only ten pianists would advance: Vincent Ong would be eliminated, and Hyo Lee would not replace him.

Taken together, these comparisons show that the proposed cumulative procedure leaves the leading results largely stable, while its practical effects are most visible near the qualification boundaries.

References

- [1] National Fryderyk Chopin Institute, *Regulations of the 19th International Fryderyk Chopin Piano Competition*, Warsaw, 2025, Section XIII.
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- [3] H. H. Bauschke and P. L. Combettes, *Convex Analysis and Monotone Operator Theory in Hilbert Spaces*, Springer, New York, 2011.