METHODOLOGY FOR PROCESSING OF THE JUDGE RATES IN THE CONTEXT OF AEROBATIC COMPETITIONS

METODOLOGIA OBLICZANIA OCEN SĘDZIOWSKICH W RAMACH ZAWODÓW AKROBACJI LOTNICZEJ

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Abstract: Aerobatics is a sport whose specificity significantly differs from other air disciplines. Aerial figures performed in a confined space (referred to as a 'box') are a challenge not only for the pilots, but also for the jury evaluating the competition. Subjective scores of the judges are converted by a dedicated FPS (Fair Play System) system. FPS is the basis for the ACRO scoring software (Aerobatic Contest Result Organizer) used to convert and publish the results of aerobatic contests organized worldwide. Due to the multi-aspect nature of data processing, the system is not always understood by the players. The paper attempts to explain various stages of calculations and explore issues associated with standard judging. This aspect is extremely important, not only for the competing pilots, but also for the judges and the viewers.

Keywords: aerobatics, data processing software, judging the aerobatics competition

Streszczenie: Akrobacja lotnicza stanowi dziedzinę sportu, która swoją specyfiką znacznie odbiega od pozostałych dyscyplin lotniczych. Ewolucje powietrzne wykonywane w ograniczonej przestrzeni stanowią wyzwanie nie tylko dla zawodników, ale również arbitrów oceniających pokaz. Subiektywne noty sędziów przeliczane są przez dedykowany akrobacji lotniczej system FPS (Fair Play System). Na jego podstawie powstało oprogramowanie ACRO (Aerobatic Contest Results Organizer), które wykorzystywane jest do przeliczania oraz publikowania wyników zawodów lotniczych na całym świecie. Ze względu jednak na wieloaspektowość procesu przetwarzania ocen sędziowskich, wynik końcowy nie zawsze jest dla zawodników jasny i zrozumiały. W pracy podjęto więc próbę wyjaśnienia poszczególnych etapów obliczeń oraz zgłębienia zagadnień związanych z prawidłowym arbitrażem. Aspekt ten jest niezwykle istotny nie tylko z punktu widzenia pilotów-zawodników, ale również sędziów oraz obserwatorów.

Słowa kluczowe: akrobacja lotnicza, system przetwarzający oceny sędziowskie, sędziowanie zawodów lotniczych

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1. Introduction

Irrespective of the sports discipline, judging competitions is an activity that requires many years of experience, precise knowledge of the regulations, observance and the ability to maintain objectivity. All these features determine the standard of appropriate judging. A multitude of detailed principles and the rank of the competition contribute to making mistakes in the evaluation that may have impact on the final results. Depending on the level of complexity of a given sports discipline and its dynamic or stationary nature, one may distinguish the levels of advancement of the competitors. As the preparatory methods and the possibilities of application of new technologies in the training process advance, competitive sports are becoming increasingly precise and require greater concentration and accuracy. Unfortunately, the standards of objectivity and conscientiousness are not always maintained.

The nature of air sports makes them particularly difficult to evaluate. Aerobatic figures are performed at large distances from the judges often under difficult weather conditions, which makes the flight and the score evaluation a difficult process. An aerobatic figure is performed within a specified tri-dimensional space (box) (Fig. No 1), which constitutes an additional obstacle for the judges evaluating such things as position of the aircraft in the zone (SP). The performance of the competition flight is based on carrying out by the pilot of a sequence of figures within a given 'Known', 'Unknown' or 'Free Unknown' competition.

Fig. 1 Presentation of the glider aerobatic zone [3]

All scores obtained by the pilot are converted with the *FairPlay System* (FPS) statistical method that was developed especially for the aerobatics competitions. The authors of the FPS rule are dr. Steven Green, prof. Derek Pike and Alan Cassidy. FPS was first presented in 2006 during competitions organized by CIVA. The main reason for the development of the system was the need to systematize the judge evaluations and eliminate situations when scores appear that are much divergent from the other scores. Owing to FPS, all anomalies are replaced with a statistical value, which allows preserving the rule of fair competition and evaluation [4][5].

Based on FPS, Nick Buckenham, current president of CIVA, developed software enabling entering, processing and printing of the competition results. The system is known under the name of ACRO and is used by the judges and organizers of championships around the world [4]. Since 2008, when CIVA started using the system, it has been used in competitions during over 50 international events [6]. The characteristics of glider aerobatics and the principles behind the FPS rule and the ACRO software have been presented in Chapter 2.

The main reason for taking up by the authors of the topic of analysis of functioning of the FairPlay and ACRO systems is the motivation to fully explore the schematics of their functioning. Wide experience of the authors in this respect hints that the principles of competition score calculations are not entirely accurate. Consultations with the pilots of the Polish National Team of glider pilots (long established top of the list of aerobatic pilots) led to a supposition that the final results of the competition obtained in ACRO are not always a faithful reflection of reality. The principles of operation of the software are unclear and complicated for the competitors (and judges). The fact of calculating by the system of penalty points when crossing the aerobatic zone are hard to understand even though the values are clearly determined¹. Negative points should be subtracted from the sum of the judge rates processed by the system to get an obvious value (pursuant to pt. 2.1.1.3. *Sporting Code, Section 6, Statistical Method for Processing Scores*, and the formula for the final score of the competitor $FS(p)=PS(p) - Pen(p)$) [12]. It is, thus possible to presume that the FPS or ACRO systems have a hidden defect, which may lead to wrong interpretation of the results. There is a need to analyze the software in terms of calculating of the negative points that are integer numbers, which is not reflected in the general score.

In order to confirm or reject the above theorem, it is necessary to perform a simulation consisting in entering the scores of all pilots obtained in the competition in to the ACRO system and comparing them with the final values processed by the proprietary judge score calculation system developed for this particular calculation.

¹ The situation has happened many times; recent examples were the Championships of Poland in Aerobatics (Radom, 2016) and World Championships in Glider Aerobatics (Toruń 2015). The change of the score led to mixing of the entire rank, which is unclear and frustrating for the pilots. Upon applying penalty points for the competitor and including them in the system, the ranks of all pilots changed (change of individual scores). This allows a statement that there is a correlation among the scores of individual competitors, which should not be the case.

The authors of this paper wish to extend their knowledge on the ACRO system, in order to exclude errors in the algorithm. The knowledge gained will be used in the process of pilot training and preparation for competitions. At the same time the competitors will better learn the principles of operation of the system that decides about the order of competitors in the rank.

2. The score system of aerobatic flights during competition

Judging aerobatic competitions is accurately determined and restrictively supervised by CIVA - *Commision Internationale de Voltige Aerienne* being a part of FAI - *Fédération Aéronautique Internationale* [2]. All guidelines related to the competition, programs, methods of judging and processing the score are contained in the FAI *Sporting Code* published annually, available for download at the Federation website. The document is divided into sections that describe individual air competition disciplines. Aerobatics is described in section 6 of the document. In the first part, the FPS system and the air competition are described while the second part describes the principles of glider aerobatics [7].

The glider aerobatics programs are played in two categories: *Advanced* (AG) which is higher and *Unlimited* (UG), which is professional, competitive. Each component of a given program (aerobatic figure) is evaluated by the judges and then calculated according to the K factor (index of the figure weights). The figures contained in the program of the UG category have a higher K factor due to the difficulty level (table 1). In order for the competition to be qualified as valid, a minimum of three (Free Known, Free Unknown and Unknown), and a maximum of six competitive events (Unknown 2, 4, 5, 6) must be played. All components of the programs have been presented and described in detail in the CIVA –*Aresti Aerobatic Catalogue* (Fig. nr 2) [1]. The difference among individual competitions has been described in table 1.

Fig. 2 Figures included in the ARESTI catalogue[10]

The performed flights determine the individual and team winners in general classification. Additionally, medals go to the winners (first three places) of individual programs [1]. Aside from evaluating individual figures, judges also evaluate the position of the aircraft in the aerobatic zone (Fig. 1 and 2) and the harmony² of the flight. Qualified and experienced panel of judges can provide an expert opinion on various artistic and technical aspects of the competition show. For each flight off the box negative points are applied; the excess of the bottom and top limit results in the highest penalty and, in extreme cases, even in disqualification of the pilot (descending below 100 m). The exact aerobatic zone is between 200 m and 1200 m over the airstrip. The dimensions of the cuboid are 1000x1000x1000 m plus the additional buffer zone – 50 m from each side. The *box* is marked on the ground with markers– 2x9 m sheets of white canvas in the zone corners, the zone center and two axes: the main and the auxiliary one (Fig. No. 1). The competition flight must be performed within the main axis of the show and the program begins when the pilot sends a signal with three wing waves from the horizontal position. The same signal is sent when the pilot finishes the show. The score is given only in between the pilot's signals, which is important in terms of maintaining the position within the zone 2x9 m.

The judge stands are located perpendicularly to the center of the aerobatic zone and the main axis of the show at a distance between 150 - 250 m from the wall of the *box* (Fig. No. 2) and the competitors cannot approach them closer than 20 m. There must be at least a 15 m separation between the judge stands. During international competitions, at least 7 (maximum 10) judges are required [11]. Each of them fills out a program sheet of the competitor (the sheet includes the figures). The scores are given on the scale from 0.0 do 10.0 with a half-step interval [5]. The following grades can also be given under extraordinary circumstances [11, 13]:

- PZ (*Perception Zero*) – if difficult-to-determine technical mistakes in a figure occur;
- HZ (*Hard Zero*) – carrying out a different figure than the one declared in the sheet;
- AV (*Avarage*) – if the judge misses a figure, an averaged score by FPS can be applied for.

² 'Harmony of the flight is evaluated according to the following criterions:

- energy management
- maintaining rhythm
- separation of figures
- control of the flight direction [11].

Tabl. 1 Programs of glider aerobatics [11, 12]

	Free Known (program 1)	Free Unknown (program 3)	Unknown (program 2,4,5,6)
Number of figures	10	8-9	7-10
Figures included in:	ARESTI CATALOGUE	Sporting Code, Section 6, Part 2 APPENDIX A (pursuant to ARESTI)	Sporting Code, Section 6, Part 2 APPENDIX A (pursuant to ARESTI)
Composition of the program	The program is composed of 10 figures: <ul style="list-style-type: none"> - 5 are selected at an annual CIVA conference - another 5 are chosen by the competitor according to the <i>Sporting Code</i> - the competitor is free to prepare a competition program from chosen figures 	The competitor sends his program to the jury that was prepared in the following manner: <ul style="list-style-type: none"> - not later than 24 hours before program sending deadline the judges publish 7 figures that were selected from schedule A to the <i>Sporting Code</i> - the competitor compose s a program from the 7 obligatory figures and 1 or 2 additional transitional figures - the program must be sent to the judges no later than 24 hours before the competition begins 	The sum of all figures in programs 2, 4, 5, 6 is 35; they are chosen from schedule A to the <i>Sporting Code</i> ; figures are submitted by a delegation of two competitors who draw lots; Then the judges determine further programs; If a figure was already performed it cannot be repeated; the jury chooses one of the submitted sequences that is published for the competitors not later than 12 hours before the start of a given competition
Total value of the figures	230K (UG) 175K (AG)	180-200K (UG) 140-160K (AG)	175-190K (UG) 130-145K (AG)
Training allowed	YES	NO	NO

Due to the need to stay within a strictly assigned space, which is not permanently tri-dimensionally marked, the judges are familiarized with its edges with the help of a pilot flying over the aerobatic zone and a show of a trial pilot (aerobatics of a competitor who does not take active part in the competition).

The *FairPlay* system has been developed to eliminate subjective scoring of the judges that is incompliant with the actual result of the competitor. If any of the scores significantly diverges from the rest, it is substituted with a new value being a statistical average of the other judges' scores. During the championships, the composition of the panel of judges is international, which is why it is important to systematize and equalize differences resulting from different nationalities of the judges. Additionally, each of the judges is evaluated by their own scores and then placed in a World Ranking Index that is decisive of the participation of a given judge in the coming events [13].

3. The analysis of the processing of the judge scores according to the FPS rules within the Aerobatic Contest Results Organizer software (ACRO)

All activities described in this chapter related to judge score processing by the ACRO and FPS systems have been developed based on the official FAI – Sporting Code, Section 6, International Aerobatic Events: Statistical Method for Processing Scores. Below, the main steps of the contest final results processing have been presented in a fragmentary manner.

Before the ACRO system can be used, it is necessary to enter the following data: number of pilots, number of figures for each pilot (for glider aerobatics harmony and position are also taken into account, as described above), the K factor for each figure and the number of judges for individual programs. Then, each of the figures receives its unique symbol *kkkffpp* composed of:

- *kkk* – the K factor (if the number is below 100 the first digit is 0)
- *ff* – the number of figure (if the number is below 10 the first digit is 0)
- *pp* – the pilot number (if the number is below 10 the first digit is 0).

Another step is grouping of all data, based on which the scores are processed in the FPS system. The method of ordering the information has been shown in table 2 [12].

Tab. 2 Format of grouping of the input data within the FPS system [12]

K-factor	Figure #	Pilot#	Judge 1	Judge 2	...	...	Judge j
kkk ₁	Ff	Pp	score _{1,1}				
kkk ₂	Ff	Pp					
kkk ₃	Ff	Pp					
...	...	...					
...	...	...					
kkk _n	fFf	Pp					Score _{n,i}

At this stage, the rows are given in an increasing order in terms of each component. As per Standard³ for obligatory programs (Known and Unknown) the number of pilots will determine the number of rows in a given data group [12]. The figures are grouped in a very similar way for flights within different competitions. Detailed information is provided in Chapter 3.3 Grouping Figure Grades for Analysis of the *Sporting Code* [12]. Another stage is confirming the grades denoted as HZ by the main judge and a possible substitution with different grades at a later stage of the calculations. Each inappropriately given HZ grade results in a lowering of the score of a given judge in the *Judging Performance Analysis*.

³ Except a situation when the number of pilots does not exceed 11- then the group count will be:

Number of pilots	2	3	4	5	6	7	8	9	10
Group size	12	12	12	15	12	14	16	18	20

Then, the primary grades are defined in the form $S(ff, PP, j)^4$, which are divided into uniform groups. At this stage, each grade can have a notation $Rg(fp, j)^5$.

Another step is the calculation of the average and total sums of grades for individual pilots and judges as per the instructions included in the *Sporting Code* (pages 4-5) [12].

The normalization of the groups of data in the first place covers the analysis of the non-zero grades in order to assign each column of grades given by individual judges the same standard deviation, which enables determination of identical weights for all judges [12].

$$Normlg(fp, j) = mRg(*, *) + [Rg(fp, j) - mRg(*, j)] * sdRg(*, j) / sdRg(*, j)$$

where:

$Normlg(fp, j)$ – normalized evaluation substitutes the primary grade; if the standard deviation is 0, the formula cannot be applied and the grades of the judges are to be included in the total average. Negative results are substituted with a zero value. Non-positive grades given for perception are not subject to normalization.

If

$$Rg(fp, j) = 0, 0$$

then

$$Normlg(fp, j) = 0, 0$$

The introduction of the adapted values aims at showing the expected grades that the judges should give for the performance of a given figure. They are determined based on the analysis of grades of the outstanding judges allowing for the numerical zero results (SZ), but without zero grades, i.e. HZ [12].

$$FVlg(fp, j) = mNormlg(*, j) + mNormlg(fp, *) - mNormlg(*, *)$$

where:

$mNormlg(*, j)$ – average of the normalized grades for a judge

$mNormlg(fp, *)$ – average of the normalized grades for a pilot/figure

$mNormlg(*, *)$ – average of all numerical grades in the group and for all judges

An estimation of incorrect grades needs to be carried out in order to validate them in terms of mistakes or subjectivity of the judge. A unit grade is considered as incorrect if its uncertainty deviates from the preset boundary value. The uncertainty is determined through the application of two-way analysis of variance, where, initially it is necessary to calculate the residual value. Then the degrees of freedom of the group and residual standard deviations are determined [12].

The unit uncertainty on the level of 2.24 and higher means that the final value is 97.5% for a given judge grade. Such a situation takes place particularly if the judge neglects a gross mistake of a pilot that significantly reduces the grades of other judges.

⁴ Grade given by judge j for figure ff performed by pilot pp [14].

⁵ Grade S presented by a rectangular configuration of numbers, where fp is determined by the row index, and j by the column index.

In such a case the grade should be treated as omitted and placed in the original register of primary grades, mentioned in the previous part of this paper. The mark of the grade in the register will be R2g(fp,j) [12].

The second stage of the normalization is performed to submit the missing grades removed for their incorrectness. The calculated values will serve the purpose of replacing the wrong HZ grades and the omitted grades [12].

The final results are to be ordered within a single matrix, which will be grouped according to the pilot's identification number (lowest first) and then according to the numbers of figures. The next step is the obtainment of the product of a grade and the value of the K factor each time for all figures of a sequence. The values are to be summed up to obtain the following results:

- The sum of points given by all judges for individual figures for each of the pilots:

$$SR(p,f,*)=\sum_j SR(p,f,j)$$

- The sum of points given by all judges for the entire competition flight:

$$SR(p,*,j)=\sum_f SR(p,f,j)$$

- Total results of individual pilots:

$$SR(p,*,*)=\sum_{f,j} SR(p,f,j)$$

The data processed in this manner are immediately given to the competitors [12].

Another step is the normalization of the points obtained for the sequence of figures to check the correctness of the weights assigned to individual judges. Based on the obtained data, values adapted to the sequence of figures (FVS(p,j)) are calculated along with the rest of the points for the sequence, the number of degrees of freedom for the sequence, residual standard deviation and uncertainty for the scores for the sequence of figures. If the latter from the above-listed values exceeds 1.65 (90%), it must be replaced with an adapted FVS value (p,j) [12].

The values of the grades upon summing up are averaged and a standard deviation is calculated for each judge. Upon normalization of the groups of data, it is possible to assign identical weight to all participating judges and identifying grades of uncertainty higher than 95%. Such grades are replaced with adapted values. All grades given by the judges are analyzed by the FPS system. The list of all mistakes⁶ of the judges is made available to the international jury each time after the competition ends. At the same time a judge evaluation is being created that is included in the Ranking Index [12].

Based on previous calculations a temporary final result is created being a sum of normalized points for the sequence of figures (NormS(p,j)) upon substituting the incorrect values with the adapted FVS ones (p,j) [12].

⁶ A judge mistake is understood as a grade significantly diverging from the grades of the rest of the judges and incorrect application of HZ [12].

$$FS(p) = PS(p) - Pen(p)$$

where

$$PS(p) = \sum_i \{NormS(p, j) \text{ lub } FVS(p, j)\} / N_j$$

To sum up the entire process of creation of the scores within the FPS system, the following steps are taken:

- Determination and assignment of correct HZs for judges
- Assignment of identification ‘omitted’ to unconfirmed HZ and A grades
- Combining the grades from a figure into data groups for further analysis
- Actions taken within a data group:
 - Normalization of grades to assign correct weight to all judges.
 - Assignment of values to judges.
 - Assignment of identification ‘omitted’ to each normalized grade of the uncertainty level above 95%.
 - Determination of corrected normalized grades and adapted values.
 - Replacement of omitted grades with new adapted values.
- Actions taken within a sequence of figures:
 - Normalization of grades to assign correct weight to all judges.
 - Assignment of values to judges.
 - Replacement of value of uncertainty level above 90% with adapted values.
- Actions taken within second iteration:
 - Repetition of the FPS process excluding low-graded flights.
 - Combination of results into a final ranking [12].

4. Conclusions

Upon the analysis of the algorithms calculating the judge grades within aerobatic contests, it is possible to hypothesize that currently applied software and the methodology may contain errors. This theorem will be subject to validation within the independent software currently developed at Poznan University of Technology. The functioning of the system will be based on the main algorithm designed by CIVA, i.e. *Fair Play System*, which is specifically described in the *FAI Sporting Code, Section 6, International Aerobatic Events: Statistical Method for Processing Scores* and in the previous chapter of this paper.

The development of the software from scratch will enable controlling each stage of the calculations and will provide an opportunity to address the generated results through *Acro (Aerobatic Contest Results Organiser)*.

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