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# Performance Standards in Artistic Roller Skating

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Dissertation submitted as partial fulfillment of the requirement for the degree of

MSc in Computer Science and Business Management

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September 2019

*Não sei o que virá a seguir, mas sei que será melhor ainda.*

# Abstract

Figure skating is an increasingly popular sport in Portugal, with a growing number of athletes involved. It is therefore imperative, to closely monitor any anomaly that may exist. The accumulation of data from the championship results and the fact that no studies have been done before with the results of Figure Skating on wheels, makes it an advantage to do it now.

Since the Skating judging system is in a transition period, it is important to understand what was the comportment of the last few years, so that it can be compared later with the new system to be implemented.

For the development of this dissertation, a problem was identified and analyzed through data mining techniques and statistical tests, in order to achieve results that prove if there is a problem with the current judging system. The overall problem identified was the final results obtained by athletes in European Championships of the last 8 years.

As mentioned above, data mining techniques were used, more precisely a sensitivity analysis model was constructed. Data used as input to the sensitivity model and statistical tests were provided by the Federação de Patinagem de Portugal. To define some metrics such as when an athlete's results are biased, the feedback was collected from coaches and judges.

With this dissertation, it was possible to realize that there is a relationship between the final position of the athlete and the place where the championship takes place, as well as the nationality of the judge and the athlete. However, it is not possible to support the origin of the bias identified in the results once it can be unconscious.

**Keywords: Data Mining, Artistic Roller Skating**

# Resumo

A patinagem artística é um desporto cada vez mais popular em Portugal, com cada vez mais atletas envolvidos. É, portanto, relevante acompanhar de perto qualquer eventual erro no processo de avaliação dos atletas nas competições internacionais. O acumular de dados dos resultados de campeonatos e o facto de até ao momento não ter sido feito nenhum estudo sobre as avaliações dos juízes em competições de Patinagem Artística sobre rodas, faz com que seja uma mais valia fazê-lo agora.

Uma vez que o sistema de ajuizamento da patinagem se encontra em período de transição, é importante perceber qual foi o comportamento dos últimos anos, para mais tarde ser possível fazer uma comparação com o novo sistema a ser implementado.

Para o desenvolvimento desta dissertação foi identificado um possível problema (enviesamento na atribuição de notas em competições internacionais), sendo este analisado através de técnicas de Data Mining e testes estatísticos. O objetivo é o de se encontrarem resultados que comprovem se se está realmente perante alguma falha no sistema de ajuizamento. Foram analisados os resultados finais obtidos pelos atletas em Campeonatos da Europa dos últimos 8 anos. Tal como referido acima, foram utilizadas técnicas de Data Mining, mais precisamente foi construído um modelo de análise de sensibilidade.

Os dados utilizados como input do modelo de sensibilidade e dos testes estatísticos foram fornecidos pela Federação de Patinagem de Portugal. Para se definir algumas métricas tais como, quando é que se poderia considerar que um atleta teria o seu lugar enviesado, foram consultados treinadores e juízes.

Com esta dissertação foi possível detetar que existe relação entre a posição final do atleta e o local onde decorre o campeonato, assim como a nacionalidade do juiz e do atleta. Contudo, não é possível afirmar a origem do enviesamento identificado nos resultados, isto é, se o enviesamento é intencional ou não.

**Palavras-Chave:** Data Mining, Patinagem Artística

# Acknowledgments

The day as come, it is the end. I can proudly say I finished my dissertation and what a journey it was. This paper is much more than just a research to me, it is the opportunity to combine my life's passion with my university work. However, I couldn't reach this point without some special persons who was always by my side supporting me during this process, as:

My parents, my brother and my grandparents who always supported and encourage me to be better and want more for myself. I know I can always count on you no matter what.

Cristiano, who helped me to get through the bad days and was always available to put a smile on my face, you are awesome.

My friend from kindergarten Diogo Cardoso, who made me understand the meaning of "minimos olimpicos" and always believed in me.

João Gato, my friend and colleague from artistic roller skating, who is also coach and judge, thanks for technical revision, your knowledge was precious.

My friends and colleagues who supported me during this journey, a simple thanks will never be enough.

Last, but not least, I want to thank my supervisors, Pedro Ramos, and Sérgio Moro, for supporting me and guide me. Your knowledge and wisdom made possible this accomplishment.

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# Chapter 1 – Introduction

## 1.1 Introduction

In the last years, we've been witnessing a huge skills improvement of artistic roller skaters in Portugal. We can see that by the results at the European Championships getting better year by year. With the increase of new skaters and the better results of the Portugal team, it's mandatory to analyze and study to keep getting better.

Following the improvement of technology, some sports started to use some techniques to guarantee the fairness of judgment and to make sure that any athlete is impaired. Those techniques are considered a big challenge to some sports, not only because it's necessary to admit that things, as they work nowadays, are not the better solution but also because it takes time and money to study them and to implement.

The purpose of this work is to get a better view of European Championships results and understand if there are external factors capable to influence directly or indirectly the skater's scores.

Achieving conclusions that show that the current system used to evaluate skaters are not the fairest, it's a big step to make an impact and make it change. It is really important, more than ever, to have a trustable judging system to improve the artistic roller skating as a sport in Portugal and in Europe.

The aim of this research is to find evidence of any kind of bias at the artistic roller skating European championships from 2007 to 2018. It is intended to prove that there were factors that influenced the final scores during the period of time mentioned for this type of sport since there isn't any evidence of previous research about it.

There is a lot of subjectivity present in the current judging system of artistic roller skating, which instigates to have unfair scores. The big problem is to understand when bias is being conscious or unconscious as judges can have a special preference for a type of style and not because of the athlete.

For the present study, it will be considered the following types of bias: national bias and home advantage. Assuming that national bias occurs when a judge give higher marks consciously to

a skater with the same nationality as him and home advantage happens when a skater has a better performance because the championship takes place at his own. Both types of bias have subjectivity since we can't be absolutely sure about the factors that influence both biases.

However, it will be studied the results in order to understand if there are any changes that could get judging more fair for all skaters. As an example, changing the current judging system for something more technological since the huge improvement of technology devices nowadays.

## 1.2 Research Questions and Objectives

External factors can influence the final score of a skater. Factors as the place where the Championship takes place or the judges chosen for the group of judges.

The aim of this research, it is to answer two big questions:

1. Does the local where the Championships take place influence the skaters?
2. Do the judges are biased to score skaters by their nationality?

It will be used date from European Championships from 2010 to 2018 of all disciplines. To achieve conclusions it will be take into consideration the types of bias studied previously and politic factors (also studied before) to understand if it can influence sports events.

## 1.3 Methodology

This work will start with a well-identified problem, in order to find if there is necessary to do some changes to the current system that's being used by the Confédération Européenne de Roller Skating (CERS).

The results needed to extract information will be provided by the Federação Patinagem de Portugal (FPP) making them trustable and reliable. It will be used scores of European Championships and European Cups from 2007 to 2018.

Data collected will be analyzed through a data mining approach considering the advantages that this technique presents for extracting knowledge of a considering amount of a dataset.

## 1.4 Document Organisation and Structure

This research is organized by chapters. The first one, it is intended to give an overview from all the study: the purpose, the methodology used, the results and the discussion with a conclusion. The second chapter shows all the studies that have been done before related to my investigation covering subjects as the involvement of society in sport, rules and the current judging system for European Championships, types of bias and data mining techniques studied before. Next, it is explained how data were worked to fit the sensitivity model.

After that, it is shown the results got by the sensitivity analysis model. To conclude, there is a sum-up of the results and a possible future work.

# Chapter 2 – Related work

This chapter presents all the knowledge found for the subject in the study, focusing on sports especially artistic roller skating and judging bias.

## 2.1 Sports and the Society

For those who practice sport, it's not only about to do some physical exercise, it's a way to express themselves, to focus on something they are passionate about, to challenge people and make them proud of their achievements (Jackson, 2013). Although their importance, it's not taking much importance in society nowadays, people still associate sport with childhood play and leisure time.

In spite almost everybody already had an experience with the sport, it's not guaranteed that it was a good one. People can associate sport with a bad experience in their lives, it can be associated to a culture where, in some kinds of sports, athletes are highly paid for the skills they present or also it can be linked to violence by fanatic fans (Jackson, 2013).

Also, sports can be related to traditions in society (Maguire, 1994) and can show contrasts on the development of different societies. The environment of each culture, the conditions of people's living, their beliefs and the knowledge they are surrounded by, are important to define the kind of perspective they will have about sports. Furthermore, in the same society sports can make a huge impact when defining social groups.

In other words, sport has the power to shape cultures by label a nation and creating a competitive community at societies. This rise a type of nationalism in specific nations where sports have a huge role at the society and for the economics (Maguire, 1994).

Sports events have the power to get together people who enjoy a type of sport and people who support the same team, it's linked to "passion, excitement, drama and human performative excellence" (Jackson, 2013). However, it can bring also violence, when people get too excited and can divide and make a wide contrast between groups (empowering some and oppressing others).

As (Jackson, 2013) research showed, the location of some types of sports can be related to political, economic and cultural/national issues. Should have careful attention because it involves competing social matters increasing violence and it requires a lot of investment of natural and financial resources which could be used in other events more important at the perspective of some society groups. It was also showed that, all over the world there are differences of sports popularity which increases variances between public and private interests.

At the same study, (Jackson, 2013), focused on the 2011 Rugby World Cup and the slogan used “stadium of 4 million” at New Zealand. The promotional campaign to the Cup had a real impact because it brought people together and it showed a united nation, but also there was a big problem, it was necessary to construct new stadiums and improve public facilities Having the possibility for the realization of the Cup it wouldn’t be only a spending effort for the government, it would also translate in a private expense for the citizens.

It is important to focus that sports have an important role in society, it provides a social benefit by only participating in some kind of sport; also it increases expectations about a nation who is expected to have a high performance which is really helpful in international development contexts; however, researches about sports still show that sports’ social impacts are unsatisfactory (Kay, 2009).

## 2.2 Artistic Roller Skating

Artistic Roller Skating is a sport that combines technical performance with artistic performance, in order to execute elements in perfect harmony with music, and can be executed individually, in pairs or in groups.

According to (FPP, 2018), the first reference to the use of skates is by Paulo Soromenho, when in the middle of the year 1873, D. Maria Pia presented the first roller skates that were known. Other reports of this time give us an account of the existence of skates in the Palace of Mafra brought from Paris. From its origins, the skating is directly linked to the elegant and aristocratic of the Portuguese society.

As a sport, the Skating appeared in Portugal in the '50s. If initially, the Skating had a little expression, later it was affirmed in the Portuguese society as a recreational modality, in which the people registered to learn to skate, in order to have some fun. At the time, Shows were organized and the "Skating competitions" were organized in which, after the performances of

the athletes, the public placed their vote in an urn, taking into account skating, naturalness, elegance and perfection of skaters.

However, it was in the '70s that the Artistic Skating verified the fastest growth, with a significant increase of athletes and clubs.

The Portuguese team has won the first gold medal with Rita Falcão in 1999, in both the mandatory and the combined European Championship in Germany. This result was historic because, for the first time, the National Anthem was heard in Senior competition. In World Championship, Portugal won the first gold medal in 2009 at the World Championships in Germany. He was the first Portuguese world champion in the Solo Dance variant with two maximum marks (FPP, 2018),

This sport can be divided into four disciplines: Mandatory Figures, Free Skating, Solo Dance and Show and Precision. Athletes are divided into groups according to their age. For European competitions, the current levels are minis (10 and 11 years), Espoir (12 and 13 years), cadets (14 and 15 years), youth (16 and 17 years), juniors (18 and 19 years) and seniors (+19). The European Cup is aimed at skaters from minis to youth and covers the disciplines of free skating, compulsory figures, and solo dance. The Europe championship is designed for skaters from cadet to senior and covers the disciplines of free skating, compulsory figures, and solo dance.

The group of judges for the European Championships and the European Cup is chosen by the president and vice-chair of the CERS (Confédération Européenne de Roller Skating), subject to their availability. Both choose based on the official list of judges drawn up by the World Figure Skating Committee. The group of judges consists of 5 judges, one referee and one assistant referee for the European Cup and for the European Show and Precision Championship consists of 7 judges, one referee and one assistant judge-referee for the remaining European Championships (cadets, youths, juniors, and seniors) (RuleBook CERS, 2018).

Scores in this sport (for any discipline) range from 0.0 to 10.0 points and are awarded depending on the athlete's test performance. Variations of grades at the decimal level are used to distinguish skaters. The body of judges is not allowed to consult any auxiliary means to assign/decide on the note of a skater. Each judge assigns two notes to a skater, notes A and B. In note A, they evaluate everything that is related to technical elements, such as jumps, spins, steps, is evaluated. In a note, B is evaluated everything that is related to the scheme executed by the athlete, as well as music, choreography, interpretation, creativity and the skater's involvement with the music.

The scores given by the judges are all summed and with that punctuation, it is given to the skater a place in the rating table. However, when the judges assign a score to the skater they are also assigning a place to the athlete. The first skater of a specific group counts as a standard score, and the next athletes receive a grade superior or inferior to that one. As we can see in ***Figure 1***, each judge assigned a place to the skater when they attributed a score. That can influence the final rating of a skater because he can have a higher final score but it can stay in a lower rating position. As we can see, a skater at the 7th place had a final score of 106.100 and the skater at the 8th place had a final a score of 106.700. It happened because when we look to the places that judges attributed to each skater, we see that the one that is in 7th place had more judges putting him up in the rating scale instead of the one that is in 8th place that had more judges placing him in a lower position of the rating scale (Regulamento Técnico Português, 2018).

*Figure 1 - Example of final results*

| | Name | Nation | Points | M.V. | Rule | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Giada Luppi | ITA | 127.900 | 20.0 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | Daria Alexandra Matei | ROM | 122.600 | 19.0 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | Sofia Paronetto | ITA | 111.400 | 18.0 | | 4 | 3 | 4 | 3 | 3 | 6 | 4 |
| 4 | Carla Mendez Vela | ESP | 112.100 | 17.0 | | 3 | 4 | 5 | 4 | 5 | 4 | 3 |
| 5 | Lucia Fernandez Otero | ESP | 107.500 | 16.0 | | 5 | 7 | 3 | 6 | 9 | 5 | 5 |
| 6 | Daniela Meireles | POR | 106.100 | 15.0 | | 6 | 5 | 7 | 8 | 4 | 7 | 7 |
| 7 | Emilia Li Michel | GER | 106.700 | 14.0 | | 9 | 8 | 8 | 5 | 6 | 3 | 6 |
| 8 | Emilia Jarczewski | GER | 103.700 | 13.0 | | 7 | 6 | 6 | 7 | 7 | 9 | 8 |

The explanation with more detail of the white system impact it is in ***Table 1.*** It shows an example of punctuations attributed to an athlete's performance.

| Athlete | Judge 1 | Judge 2 | Judge 3 | Judge 4 | Judge 5 | Total |
|---|---|---|---|---|---|---|
| **1st Place - A** | 7.2 (2) | 7.3 (1) | 8.1 (1) | 8.4 (2) | 8.2 (1) | 39.2 |
| **2nd Place - B** | 9.1 (1) | 7.2 (2) | 8.0 (2) | 8.5 (1) | 8.0 (2) | 40.8 |

*Table 1 - White system explanation*

The numbers in parenthesis are the place that a judge attributed to an athlete when they scored him. A judge gives punctuation between 0 and 10; that punctuation it is converted to a place; if an athlete has more judges who put him up on the final ranking he will be better classified even if he had lower total punctuation as it is shown at ***Table 1***.

Athlete A got the 1st place but lower total punctuation compared to athlete B who got the 2nd place. This happened thanks to white system, athlete A got more judges putting him in 1st place than athlete B.

As this can happen, we can have skaters with a higher final score but in a lower place in the rating scale.

Skaters should only be evaluated by their performance and not by any external factors such as expectations, uniformity of judgments, the order of appearance or national bias as (Whissell, Lyons, Wilkinson, & Whissell, 1993) emphasized. Any of these factors could imply a different final rating score and in consequence months of hard work.

There are different ways to be eligible to a European Championship or to a European Cup for a skater. At European Championship, the skaters chose are those who scored higher at the Portuguese National Championship. European Cup works as a second chance for skaters who didn't get a podium at the Portuguese National Championship but are considered as good skaters for the National team. It is organized some events in each district and skaters are selected by their performance in those events. This is an important part that it's contested at sports mega-events.

## 2.3 Different Types of Bias

There are a lot of research studying the effects of biased judging in sports competitions, such as Ansorge & Scheer, (1988) in Gymnastic; Emerson, Seltzer, & Lin (2009) in Diving; (Zitzewitz, 2006; Looney, 2012; Whissell et al., 1993; Campbell & Galbraith, 1996; Findlay & Ste-marie, 2004; Nigel J. Balmer et al., 2001), in Figure Skating; (Zitzewitz, 2006) in Ski Jumping; Myers, Balmer, Nevill, & Al-nakeeb, (2006) in Muaythai; Balmer, Nevill, & Lane, (2005) in Boxing.

They didn't just focus on analyzing the results of competitions, they tried to demonstrate and to find explanations for those results found. Bias got a huge concerning part nowadays, not only because we're fighting for fairness everywhere and every day but also because with the improvement of technology it's getting mandatory to get better ways unbiased to score athletes.

As previous researches demonstrate, we can't focus only in national bias, there is other bias to consider, as reputation bias (Findlay & Ste-marie, 2004) and home advantage (Nigel J. Balmer et al., 2001) and (N. J. Balmer et al., 2005). The most common problem found to address any

conclusion to the studies was the subjectivity used at judging this type of sports Emerson, Seltzer, & Lin (2009), (Zitzewitz, 2006), (Campbell & Galbraith, 1996) which can be related to not know when bias was conscious or unconscious.

There was interest in two kinds of bias patterns for Ansorge & Scheer, (1988): bias in favor of the gymnasts from judges' own countries, and bias against gymnasts from countries in close competition. They were focused on finding any pattern of bias by men's and women's gymnastics judges at the 1984 Olympic Games. To achieve those guidelines it was used the complete results and judging assignments from both team compulsory and optional competitive sessions since the composite of the two sessions determine the final team placement.

To verify if there were biased judges in favor of their own country and against gymnasts from countries in close competition with their own, it was compared the score from each individual judge with the mean of the remaining three judges on the panel. The purpose of using this method was to prove that judges score gymnasts from their own country higher than the average of the other three judges and score lower the gymnasts from the closest two countries in the competition than the average of the other three judges on the panel (Ansorge & Scheer, 1988).

As they expected, the results show evidence of international bias in gymnastics judging at the 1984 Olympic Games and they were able to say that those biases appear in two distinct ways. At that competition, it was verified that 282 times gymnastics' scores were higher when judges scored gymnastics from their own country and lower only 29 times when compared with the mean of scores from the rest of the judging panel. In another hand, when comparing gymnastics' scores from countries close to their own, it was shown that 399 times scores were lower and 190 times higher, when compared with the mean of scores from the rest of the judging panel (Ansorge & Scheer, 1988).

Emerson, Seltzer, & Lin (2009), studied the diving competition of the 2000 Summer Olympics. They proposed a linear model however, some difficulties addressed were related to the incomplete set of interactions between judges and diver nationalities. With their research, they found evidence of nationalistic bias in the judging but they emphasize that the term "bias" used in their study, has a particularly negative connotation. They were not able to guarantee if the "bias" found were intentional or if they were related to preferences for some kind of style (which could be correlated with nationality). Although, it was found evidence of primary judging bias (national bias) they weren't noteworthy. For future studies, they propose research with multiple competitions.

For (Zitzewitz, 2006) the purpose of his study was to demonstrate that making decisions in organizations can show bias, like when it's necessary to promote someone or give them a project. As it was really difficult to study that in an organizational context, it was analyzed judging of 2002 Olympics, in particular, figure skating and ski jumping.

In figure skating, Olympic judges are the only ones who influence the final scores, in other words, the entire judging process is subjective who gives judges the opportunity to influence scores. Specifically in figure skating, (Zitzewitz, 2006) found that this kind of bias (nationalistic biases) translates to an average placement 0.7 positions higher. In both sports, judges score athletes from their own nationality 0.13 higher than other judges and there are three basic important points:

1. Nationalistic biases are dependent on career concerns;
2. Judges biases interact strategically. If a country doesn't have a judge represented on the judging panel it is in a huge disadvantage;
3. The current methods for aggregating judges opinions appear to place too little weight on extreme opinions.

It should be taken into consideration an important point. It's hard to distinguish favoritism from the taste, and in sports, this can be a problem since it's impossible to know if a judge' score is influenced by his personal taste or any bias. A judge can prefer a personal type of style, and give a higher score according to that, it doesn't mean it is intentional (Zitzewitz, 2006). He was able to find out that the degree of bias varied according to the stakes of the competition when judges' scores were higher on athletes with the same nationality.

Also, Looney, (2012) studied judging anomalies at figure skating, but in his case, he focused on the 2010 Winter Olympics in men's categories. It was analyzed the new scoring system for Olympics, after the big judging scandal in 2002. Although the International Skating Union believed that the new system was fairer for skaters, it also kept the same previous problem: there was an enormous subjectivity evaluating the program components, as skills, choreography, interpretation, and transitions, because are the most easily manipulated by the judges.

One more research was made by (Campbell & Galbraith, 1996), who developed a nonparametric test to verify the null hypothesis of unbiased judgments. Although they had results that contradict the null hypotheses of unbiased judges, the evidence of nationality biases was quite small. So, with these results that are some important points to focus. First, as in any

competition, there is a very strong possibility to have a judge from each skaters' nationality, it decreases the probability of advantages for competitors because judges from different countries are equally biased. Second, as estimated biases aren't that higher, it is kinda probably that the final ranking wouldn't be much influenced. And, finally, as already shown by Emerson, Seltzer, & Lin (2009), it's not possible to be absolutely sure that the bias verified aren't unconscious, because a judge can be most related to some type of skills since there is such subjectivity in this sports judgment.

Another kind of bias that can be found when judging sports, is reputation bias. This kind of bias is related to when judges score athletes based on whether they know them or they don't. If a skater is well known they have higher chances to get better scores than those who are unknown for the judges, that's what (Findlay & Ste-marie, 2004) showed with their research. Not only if the judges know the skater but also by the expectations created increased by the positive reputation of the skater.

To achieve conclusions they chose 14 female figure skaters to be evaluated by 6 judges from the Eastern Ontario section of Skate Canada and 6 from the Québec section whether they were known or unknown. The judges were from different sections to have judges who knew some athletes and others who don't, in spite of all judges believed that all skaters were from the same general region. To make it impartial the judges didn't know the purpose of the study, only at the end were they informed. It's was created an ordinal ranking and the higher ones happened when skaters were known by the judges when compared with when they were unknown. Also, they were able to demonstrate that the difference found was on the technical marks which were higher for known skaters and the artistic marks didn't have much influence (Findlay & Ste-marie, 2004). However, the difference found on the technical mark would have a significant impact on skater's final placement.

There is also evidence of home advantage at the Winter Olympics from 1908 to 1998, according to (Nigel J. Balmer et al., 2001) research. To reach some conclusions there are three important factors for the study: subjective officiating, distance traveled and familiarity with local conditions. To determine home advantage it was compared the medals or points won by a hosting nation with the medals or points won when the competition takes place in another nation at the Olympic Games. To avoid the problem of being unfair for weaker hosting nations, it will be compared away performance against mean home performance, making each performance like a unique standard measure of each country ("home performance").

Towards the results that showed evidence of home advantage at Winter Olympics, it was made some attempts to explain the phenomenon. It can be a reflection of a better performance of skaters due to the fact to be performing in front of a home supportive audience, however, this would happen whenever crowds were present. Another speculative explanation is that judges feel some kind of pressure to crowd noise and unconsciously score skaters higher. Familiarity with local conditions could be an explanation for home advantage however it's still too subjectively (Nigel J. Balmer et al., 2001).

Another sport that had enough evidence of nationalistic bias in judgment was Muaythai which induced Myers et al., (2006) to do some research. It was analyzed data from the 2003 World Championships that were provided by the International Federation of Muaythai Amateur. Through statistical methods, it was used a multilevel model with two levels: one where the scores are associated with the bouts and other where the bout is included as a random effect.

As a result, it was found evidence of nationalistic bias in judge's scores. However, those bias didn't have an impact on the final result, since they were diluted by the large numbers of judges. In cases where the bouts were judged by less than eight judges, the outcomes of five of the bouts were decided on by the verdict of a single judge. So it's possible for Myers et al., (2006) to say that the current system will still be functional as long as eight or more judges from different nationalities are used to judge each bout. Also, they verified that some countries didn't send any judge because of the cost, this allows the host country to get advantage from the others increasing nationalistic bias.

Another sport that was studied was boxing but in this case, (N. J. Balmer et al., 2005) tried to find evidence that there was a home advantage when bouts were decided by judges' and referees' points decisions rather than knockouts. To reach any conclusion it was used the European championship bouts results from 100 years, which also allows verifying if the results are consistent over time. It was defined what type of bouts were useful for analyzing, as for an example in the case of both boxers in a bout had the same nationality that bout would be excluded. The method used was an analysis using binary logistic regression.

Their research allowed to demonstrate that the probability of a home win against away win, were significantly higher when bouts ended in a points decision rather than a knockout. So (N. J. Balmer et al., 2005) were able to affirm that sports who involve subjective decision-making were more propitious of home advantage.

## 2.4 Data Mining

According to (Schumaker, Solieman, & Chen, 2010) “data mining involves procedures for uncovering hidden trends and developing new data and information from data sources. These sources can include well-structured and defined databases, such as statistical compilations, or unstructured data in the form of multimedia sources”.

There is a huge amount of information related to sports competition, athletes’ performance, and coach techniques. That information could be very helpful if well treated and filtered to provide a competitive advantage. As (Schumaker et al., 2010) reported, sports organizations started to use and develop better methods to extract knowledge from the data stored using data mining techniques.

Using only classical statistical analyses sometimes would not be enough to detect patterns and structures in mass data. That’s why (Wicker & Christoph, 2010) consider that it should be used data mining procedures and algorithms to identify those patterns and that it is a specially useful method for the analysis of problems of sports clubs.

Studies from (Schumaker et al., 2010) show that a problem with using sports statistics is how to measure risk. In figure skating that risk is shown by what the skaters are going to do during their performance, they can take the risk and do something harder or playing it safe and do something they really know how to do but that gives them a lower mark.

(Schumaker et al., 2010) believe that it’s necessary to have a sports knowledge management who can identify the different methods sports organizations need and the contributions of each player. That knowledge can make a difference by choosing the right players for each situation, identifying the most valuable contributions of each one, measure the tendencies of the opposition and exploiting any weakness.

(Mccullagh, 2010) used neural networks from data available including anthropometric, psychological and skill assessment to show the possibility to predict the performance of players in the AFL National Draft. The approach used was a modular neural network which intends to decompose the problem into simpler sub-tasks, with each one being handled by a separate module. With this study, it was clear that using this technique there was an improvement in performance over the single neural network approach.

Also (Haghighat, Rastegari, & Nourafza, 2013) studied the advantages of using data mining techniques to predict sports results. As it was previously explained, that's not possible with a statistic method to explain relations in data for a single game, so it's necessary to use data mining techniques to assist or to use independently in decision making. This will give sports teams advantage over other teams rivals because they can convert the data mining results into performance knowledge and improve their techniques.

# Chapter 3 – Data Mining Process

## 3.1 Data Collection

In the pursuit to conquer the best results and to achieve the proposed objectives, it is necessary to use data mining techniques. It allows finding patterns in large data sets involving methods that merge statistics, machine learning and artificial intelligence. Data mining uses machine-learning and statistical models to uncover clandestine or hidden patterns in a large volume of data.

As mentioned before through other scientific researches, data mining can be explained as the process to transform raw data into knowledge, to find patterns and to establish relationships in data. A huge part of the data mining process is a data preparation phase once it covers all activities to construct the final dataset from the initial raw data (Saluja, 2018).

As mentioned before, the data was provided by the Federação de Patinagem de Portugal. The results were archived in PDF files with the structure shown in ***Figure 2***.

*Figure 2 - Results variables*

**Youth Couples Dance • Result Compulsory Dances / Resultado Danzas Obligatorias**

| | Name | Nation | Points | M.V. | Rule | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sofia Testoni Asya / Giovanni Piccoloantonio | ITA | 111.900 | 4.0 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 2 | Caterina Artoni / Raul Allegranti | ITA | 104.800 | 3.0 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 3 | Laura Iuri / Mattia Qualizza | ITA | 99.000 | 2.0 | | 4 | 4 | 3 | 4 | 3 | 3 | 3 |
| 4 | Palmiera Seger-Suarez / Paul Turbanow | GER | 99.100 | 1.0 | | 3 | 3 | 4 | 3 | 4 | 4 | 4 |
| 5 | Paola Palomo Lopez / Juan Jose Reina Ortiz | ESP | 88.800 | 0.0 | | 5 | 5 | 5 | 5 | 5 | 5 | 5 |

| | | | | | |
|---|---|---|---|---|---|
| Referee | | | Judge 1 | M. Senesi | ITA |
| M. Brooks | | CEPA | Judge 2 | O. Colardelle | FRA |
| | | | Judge 3 | M. Escurriola | ESP |
| Assistant | | | Judge 4 | K. Laubenstein | GER |
| G. Neefs | | CEPA | Judge 5 | A. Spall | GBR |
| | | | Judge 6 | C. Versteeg | NED |
| | | | Judge 7 | H. Marques | POR |

As it is shown in ***Figure 2,*** it is possible to extract the following relevant information:

- The age group of performances;
- If it is a single ou couples performance;
- Performance's style;
- The final place achieved by each athlete;

- Athlete's nationality;
- Total points by performance (sum of punctuations attributed by each judge);
- The place attributed to an athlete by each judge (this place is a conversion of the punctuation to a place, as it is explained in ***Chapter 1 - Introduction***);
- Each judge name and nationality.

## 3.2 Data Preparation

In order to test the data and to build a sensitivity model, it is necessary to treat the data to guarantee consistent results with quality. From the provided documents by *Federação de Patinagem de Portugal*, it was extracted the following variables: ***Position, Nation, Judge_Place, Judge_Nacionality, Country, Points, AgeGroup, Sex, SinglePairsGroup, StyleType*** and ***Year.*** Based on the extracted variables, it was constructed the following new variables to help build the sensitivity model: ***MesmoPaisJuiz, MesmoPaisLocal, Judge_Nacionality, Rank_PTS, DifPositionRankPTS,*** and ***Desvio.***

### 3.2.1 Extracted Variables

| VARIABLE NAME | DESCRIPTION |
|---|---|
| **Position** | The final place of each athlete |
| **Nation** | The country where the athlete is from |
| **Judge_Place** | Place attributed to an athlete by a judge. This place is the conversion of the punctuation attributed by the judge in the form of a number between 0 and 10 |
| **Judge_Nacionality** | The country where the judge is from |
| **Country** | The country where the championship is taking place |
| **Points** | The sum of points attributed to an athlete by all judges |
| **AgeGroup** | The age group of the athlete based on his age |
| **Sex** | Indicates if the athlete it is a lady, man or pairs |
| **SinglePairsGroup** | Indicates if it is evaluating a single athlete, pairs or a group |

| | |
|---|---|
| **StyleType** | Style type of the performance evaluated |
| **Year** | Year of the championship |

*Table 2 - Extracted variables*

### 3.2.2 Constructed Variables

| VARIABLE NAME | DESCRIPTION |
|---|---|
| **SameCountryJudge** | A variable that indicates if the athlete and the judge are from the same country |
| **SameCountryLocal** | A variable that indicates if the athlete is from the same country where the championship takes place |
| **Rank_PTS** | A variable that sorts the athletes by performance based on the sum of punctuation they had (variable **Points**) |
| **DifPositionRankPTS** | A variable built to compare two variables, **Position** and **Rank_PTS**. It is necessary to understand if the final place and the place based on the sum of all judges punctuation are equal or if there is a deviation |
| **Desvio** | A variable that compares two variables, **Position** and **Judge_Place**. It is necessary to compare the final place of an athlete and the position a judge attributed, to understand if there is bias involved |

*Table 3 - Constructed variables*

To define how to find the presence of bias on final results, it is necessary to understand how many places of difference attributed by a judge, means a relevant change on an athlete final position, e.g. if a judge assigns a score to a 4$^{th}$ place but the athlete qualifies in a final position of a 2$^{nd}$ place. Does that mean we are in the presence of bias?

To answer that it was made some research with Portuguese judges. Judges are classified by what type of championships they can judge. This means that a judge can be regional, national and international judges. They grow up in their career as time goes by. It was asked to each type of judges, what they believed it was a significant difference to affirm that we are in presence of bias.

All of them considered that once there is specific punctuation to give to each element an athlete performs, shouldn’t have big differences between judges' punctuations. At least one place should be acceptable but more than that it is not supposed to happen.

The file constructed with the inputs for the model is organized having a row for each evaluation.

## 3.3 Data Analysis

Data Mining is a powerful tool to transform data into information as profit. Applying sensitivity analysis to neural network models rather than just regression models can help to identify the rate of change in the output of a model, which is caused by the changes of the model inputs. They may be used to determine which input parameter is more important or sensible to achieve accurate output values. (Yao, 2003)

### 3.3.1 Modeling

For this research, a classification Data Mining model was adopted using the ***rminer*** package of the R tool, specifically, a neural network. The network as implemented by rminer adopts a multilayer perceptron with one hidden layer of H hidden nodes and one output node.

The H hyperparameter sets the model learning complexity. A neural network with a value of H = 0 represents the simplest model, equivalent to a logistic regression, while a high H value allows the neural network to learn complex nonlinear relationships. The neural network's final solution is dependent on the choice of starting weights. The ***rminer*** package uses an ensemble of Nr different trained networks and outputs the average of the individual predictions.

The k-fold cross-validation method was adopted in order to validate the dataset. This enables all the observations to be randomly split into k equal subsets, which are used once as the test sample and k-1 times for training the model. This test sample is used to assess model reaction to new data, establishing a realistic predictive testing approach and the remaining subsets are used as training data, which is used for model building.

Sensitivity analysis is used to understand the behavior of the system being modeled, to verify if the model is doing what it is intended to do, to evaluate the applicability of the model, and to determine the stability of the model.

In order to predict whether or not an athlete will get a bias final result, it can be performed a sensitivity analysis.

### 3.3.2 Confusion Matrix

The sensitivity analysis model fit to the 23.134 training samples results in a test error rate of 14,4% - 3.323 / 23.134 = 0,1436.

In practice, a binary classifier such as this one can make two types of errors: it can incorrectly assign an individual who has their final position biased to the *no biased* category, or it can incorrectly assign an individual who does not has their final position biased to the *biased* category. It is important to understand which of these types of errors are being made. A confusion matrix, shown for the *bias* data in ***Table 4***, is a good way to display the information.

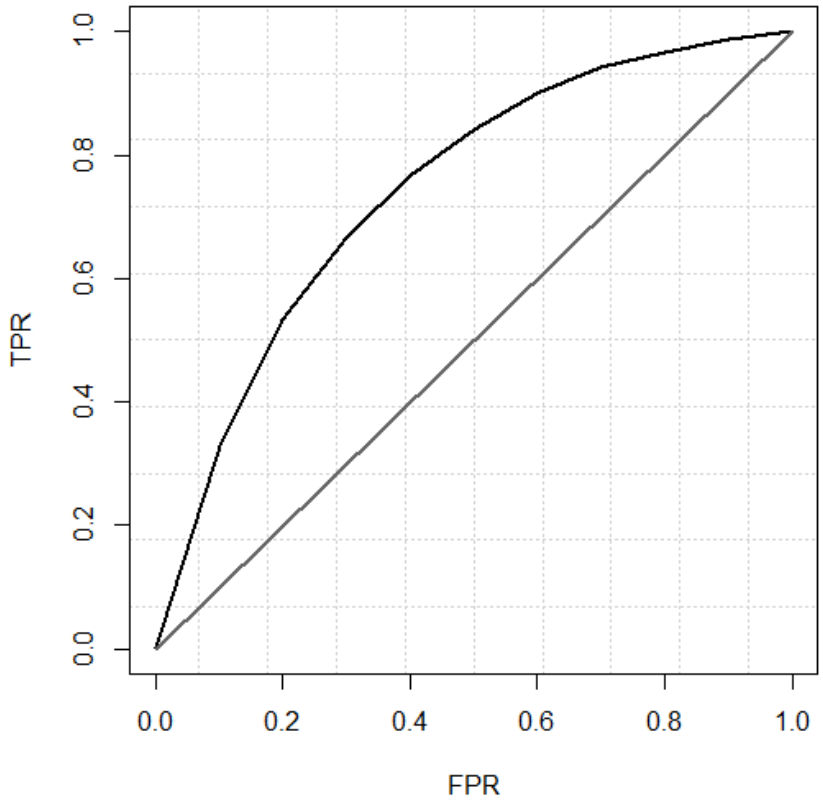
| | ***PREDICTED BIAS FINAL POSITION*** | | |
|---|---|---|---|
| ***TRUE BIAS FINAL POSITION*** | **FALSE** | **TRUE** | **TOTAL** |
| **FALSE** | 10.326 | 9.485 | 19.811 |
| **TRUE** | 568 | 2.755 | 3.323 |
| **TOTAL** | 10.894 | 12.240 | 23.134 |

*Table 4 - Confusion Matrix*

A confusion matrix compares the predictions with the true deviations observed for the 23.134 training observations in the data set. Elements on the diagonal of the matrix represent athletes whose deviations were correctly predicted, while off-diagonal elements represent individuals that were misclassified. It was made incorrect predictions for 9.485 athletes who did not have a bias in their final position and for 568 athletes who did have a bias in their final position.

The table reveals that it was predicted that a total of 12.240 athletes would have their final position biased. Of these athletes, 2.755 actually had a bias in their final position and 9.485 did not. Hence 9.485 out of 19.811 of the athletes who did not have bias were incorrectly labeled, which means an error rate of 47%. However, of the 3.323 who have a bias, only 568 were incorrectly labeled, which means an error rate of 17%. So while the overall error rate is high, the error rate among athletes who have bias is low. In this case, the sensitivity is the percentage of true bias that are identified, a high 83% in this case (2755/3323 = 0,829).

*Figure 3 - ROC Curve*




### 3.3.3 ROC Curve

The ROC curve is a graphic for simultaneously displaying the two types of errors for all possible thresholds. The name "ROC" is historic and comes from communications theory. It is an acronym for *receiver operating characteristics*. The overall performance of a classifier, summarized over all possible thresholds, is given by the *area under the* (ROC) *curve* (AUC) (James, Witten, Hastie, & Tibshirani, 2013).

An idyllic ROC curve will hug the top left corner, so the larger the AUC the better the classifier. For this data, the AUC is 0.75, which would be considered to be very good. We expect a classifier that performs no better than the chance to have an AUC of 0.5. ROC curves are useful for comparing different classifiers since they take into account all possible thresholds.

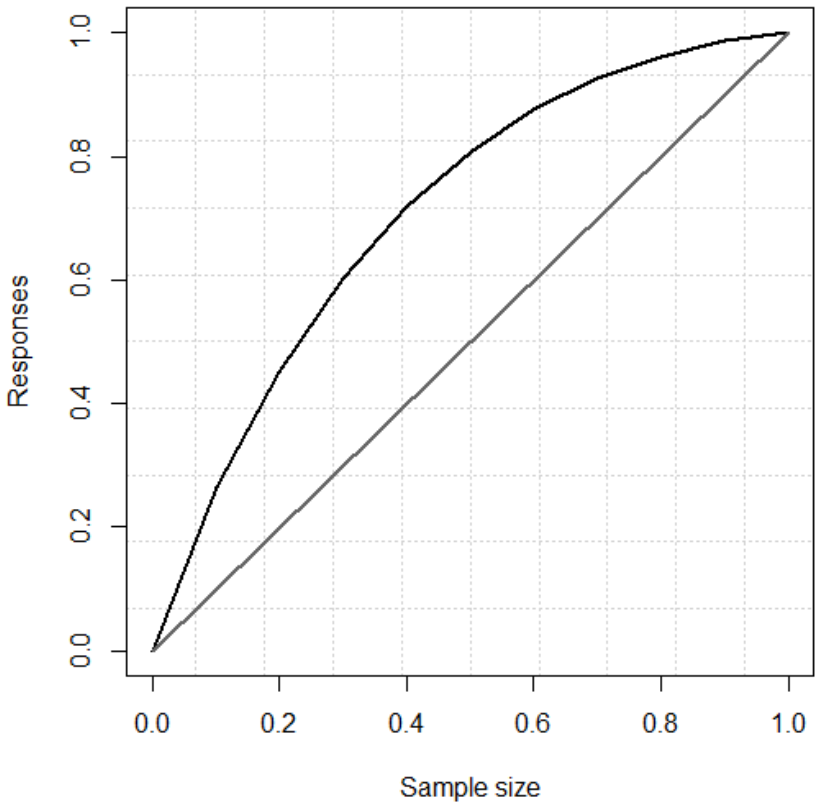
ROC curves are useful for comparing different classifiers since they take into account all possible thresholds.

It traces out two types of error as we vary the threshold value for the posterior probability of bias. The true positive rate is the sensitivity: the fraction of bias that is correctly identified, using a given threshold value. As close as the ROC curve is from the left top corner (see ***Figure 4***) the better one since it indicates a high true positive rate (83% as demonstrated before) and a low false-positive rate (52% as demonstrated before).

### 3.3.4 LIFT Curve

LIFT is a measure of the performance of a targeting model (association rule) at predicting or classifying cases as having an enhanced response, measured against a random choice targeting model. A targeting model is doing a good job if the response within the target is much better than the average for the population as a whole in this case it is possible to see that happening in the ***Figure 5***. Lift is simply the ratio of these values: target response divided by the average response.

*Figura 4 - LIFT Curve*



## 3.4 Interpretation

In order to answer the main questions of this research, it was necessary to know how the inputs used in the sensitivity model influenced the output.

### 3.4.1 Judge nationality vs Athlete nationality

It was made some calculations to find the relation between the variables ***SameCountryJudge*** and ***Desvio*** and if the relation between the two variables mentioned above were statistically significant. As so, it was achieved the results shown in ***Table 5***:

| TEST | DESCRIPTION | % |
|---|---|---|
| **SameCountryJudge** | Percentage of records where the nationality of the athlete and the judge are equal, in the universe of all records | 12.27% |
| **Desvio** | Percentage of records where there are differences between the place a judge attributed and the final place of the athlete, in the universe of all records | 14.42% |
| **SameCountryJudge vs Desvio** | Percentage of records where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete, in the universe of all records | 1.92% |

*Table 5 - Relation between nationalities and final scores*

We can consider a linear model to be statistically significant when p-values are less than the pre-determined statistical significance level of 0.05.

It was achieved a p-value of 0.0448. As the p-value is less than 0.05, there is a significant relationship between the variables.

According to ***Table 5***, 1.92% of the records represent athletes who got their final position influenced and have the same nationality as the judge who scored him.

We saw above that there is a relation between the judge and athlete nationality and the final results, now we can analyze the influence by country in those final results. The same methods were applied to find the influence by country.

| COUNTRY | DESCRIPTION | % |
|---|---|---|
| **Croatia** | Percentage of records from Croatia, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 0.22% |
| **Spain** | Percentage of records from Spain, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 19.86% |
| **France** | Percentage of records from France, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 9.59% |
| **England** | Percentage of records from England, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 5.71% |
| **German** | Percentage of records from German, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 19.63% |
| **Israel** | Percentage of records from Israel, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 1.60% |
| **Italy** | Percentage of records from Italy, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 13.93% |
| **Netherlands** | Percentage of records from Netherlands, where the nationality of the athlete and the judge are equal and there | 2.28% |

| | | |
|---|---|---|
| | are differences between the place a judge attributed and the final place of the athlete. | |
| **Portugal** | Percentage of records from Portugal, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 19.41% |
| **Slovenia** | Percentage of records from Slovenia, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 1.60% |
| **Switzerland** | Percentage of records from Switzerland, where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 6.16% |
| **Belgium** | Belgium does not have a single record where the nationality of the athlete and the judge are equal and there are differences between the place a judge attributed and the final place of the athlete. | 0% |

*Table 6 - Relation between nationalities and final scores, by country*

| COUNTRY | P-VALUE |
|---|---|
| **Croatia** | 0,488 |
| **Spain** | 0,074 |
| **France** | 0,168 |
| **England** | 0,826 |
| **German** | **0,018** |
| **Israel** | 0,098 |
| **Italy** | **0,002** |
| **Netherlands** | 3,403 |
| **Portugal** | 0,101 |
| **Slovenia** | 3,082 |
| **Switzerland** | 0,264 |
| **Belgium** | NA |

*Table 7 - Relation between nationalities and final scores p-values (bold values show significant statistic relation)*

As already mentioned, it is considered to be statistically significant when the p-value is lower than 0.05. According to results, not all countries show a statistically significant relationship between variables. ITA (Italy) is the country in which the final place is more influenced when both nationalities (judge and athlete) are equal with a p-value of 0.002. On the other hand, NED (Netherlands) is the country where the final places are less influenced, with a p-value of 3,403, which means that it is not statistically significant.

### 3.4.2 Athlete Nationality vs Championship location

Now that we can assume that there is a relation between the final position of an athlete when both judge and athlete nationalities are equal, it is time to answer one of the main questions from this research, *Does the local where the Championships take place influence the skaters*.

As done above, comparing the athlete nationality with the judge nationality impact, it is necessary to apply some calculations to find the relation between the variables ***SameCountryLocal*** and ***Desvio,*** and if the relation between the two variables mentioned above is statistically significant.

| TEST | DESCRIPTION | % |
|---|---|---|
| **SameCountryLocal** | Percentage of records where the nationality of the athlete and the local where the championship takes place are equal, in the universe of all records | 22.86% |
| **Desvio** | Percentage of records where there are differences between the place a judge attributed and the final place of the athlete, in the universe of all records | 14.36% |
| **SameCountryJudge vs Desvio** | Percentage of records where the nationality of the athlete and the local where the championship takes place are equal and there are differences between the place a judge | 2.49% |

| | | |
|---|---|---|
| | attributed and the final place of the athlete, in the universe of all records | |

*Table 8 - Relation between championships local and athlete's nationality*

We can consider a linear model to be statistically significant when p-values are less than the pre-determined statistical significance level of 0.05.

It was achieved a p-value of 0.000000268. As the p-value is less than 0.05, there is a relationship between the variable, that corroborates the percentage values found above. In this case, we are towards a really small p-value which means that the variables are highly correlated.

Therefore it is necessary to understand the weight of each country in these results. That allows us to understand which country, where the championship took place, influenced more the final results of the athletes when it is the same as their nationality.

| COUNTRY | DESCRIPTION | % |
|---|---|---|
| **France** | Percentage of records from France, where the nationality of the athlete and the local where the championship takes place are equal and there are differences between the place a judge attributed and the final place of the athlete. | 1.56% |
| **German** | Percentage of records from German, where the nationality of the athlete and the local where the championship takes place are equal and there are differences between the place a judge attributed and the final place of the athlete. | 23.44% |
| **Italy** | Percentage of records from Italy, where the nationality of the athlete and the local where the championship takes place are equal and there are differences between the place a judge attributed and the final place of the athlete. | 47.22% |
| **Portugal** | Percentage of records from Portugal, where the nationality of the athlete and the local where the championship takes place are equal and there are | 23.44% |

| | | |
|---|---|---|
| | differences between the place a judge attributed and the final place of the athlete. | |
| **Slovenia** | Percentage of records from Slovenia, where the nationality of the athlete and the local where the championship takes place are equal and there are differences between the place a judge attributed and the final place of the athlete. | 4.34% |

*Table 9 - Relation between championships local and athlete's nationality, by country*

| COUNTRY | P-VALUE |
|---|---|
| **France** | 3,277 |
| **German** | 0,51 |
| **Italy** | **0,0000001** |
| **Portugal** | 3,641 |
| **Slovenia** | 1,836 |

*Table 10 - Relation between championships local and athlete's nationality p-values (bold values show significant statistic relation)*

Making the same interpretation based on the p-value, we can see in ***Table 10*** that the lowest one is to ITA (Italy) and the highest one is to POR (Portugal). One way to interpret these results it is to say that when the championship took place in Italy, skaters with Italian nationality got a better final place than skaters from other countries. In other hands, when the championship happened in Portugal, skaters with Portuguese nationality were less influenced by having the championship in their own country.

# Chapter 4 – Conclusions and Future Work

## 4.1 Conclusions

This research allowed to take a deep look at the European Championships of the last 8 years. Making assumptions of whether the final results are biased or not it is truly dangerous once it can be put in doubt the professionalism of judges and all people involved in the championship's organization.

During the related work research phase, it was perceived that it wouldn't be easy to explain the conclusions if the results met the expectations. It was expected to find a high relation between nationalities and final results. However, even if it is proved by the results found that that happens, it is hard to explain the origin.

The results obtained with the tests made show that there are some factors that influence the athlete's final position, as the nationality of both judge and athlete and the place where the championship takes place. As shown in ***Chapter 2 – Related Work***, the influence can have different origins.

It is certain that results are influenced but it can be intentionally or not. It can be a matter of taste for a special type of performance, it can result in the skaters be more popular and the expectations be higher, it can show that skaters feel more comfortable when they perform at home or just because they have more support.

As these results are so easy to find explanations, it is hard to prove we are in the presence of conscious bias. So, it is not possible to affirm that those bias found were made on purpose. However, considering the dimension and the number of athletes that work hard every year to have the best performance, this simply shouldn't happen.

For next season (2020) it will be a changing year for artistic roller skating, once it will be tried a new judging system. This new judging system will have restricted rules and more specific values for each element and judges won't continue to have so much power over the final position. The main purpose is to have a more clear system with the introduction of a more technologic system, which is also an example of how this specific sport is trying to keeping up the evolution of technology.

## 4.2 Future Work

As mentioned at ***Conclusions*** topic, it will be implemented a new judging system. It would be really important if this research would be implemented again 8 years from now to see if there were changes for good in the judging system.

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