LEVERAGE: The Artistic Gymnastics Management Integrated Tool

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Abstract: Artistic gymnastics competitions take place according to complex regulations that are very difficult to interpret correctly even by athletes, coaches, and judges with years of experience behind them. This article presents a software named LEVERAGE aimed at managing the complexity inherent in the realm of artistic gymnastics in an easy and effective way, addressing athletes, competition judges and coaches. LEVERAGE provides all at once the features implemented by similar at cost solutions, and contains a fully digitized version of the official Code of Points (COP). Besides being fully interactive, explorable, and queryable, such COP has been reviewed and improved following the latest indications of the International Gymnastics Federation. Jointly with the other powerful capabilities offered by LEVERAGE, this modern version of the COP ease the consultation process and allows for checking correctness and score calculation of exercises' sequences. By leveraging a graph data structure, the knowledge associated with the gymnastics rules has been efficiently and effectively represented. Over this representational layer, a Relational Database Management System (RDBMS) was built to connect different gymnastics entities (gymnasts, results, teams, exercises), hence unleashing any potential further analysis.

Keywords: Sport Team management, Complexity Management, Simplexity, Knowledge Management, Data gathering

Glossary

Term	Definition
Code of Points (COP)	Official regulations document of Artistic Gymnastics
Table of Elements	Table that includes all elements and their properties
Element	Description of the movement performed by gymnasts
Originator's Name	Name of the first gymnast performing an element
Image	Stylized representation of an element
Symbol	Unique graphic symbol of an element
Code Identification Number	Unique number assigned to an element
Apparatus	Gymnastics event where an element is performed
Element Group (EG)	Group of required movement patterns, aimed to enhance the variety of elements of an exercise
Difficulty Value (DV)	Difficulty of execution of an element
Exercise	Routine of 10 elements (9+Dismount) performed by gymnasts and evaluated by the jury
Final Score	Score of an exercise, determined by the addition of the E Score and the D Score
Execution Score (E Score)	Score of the technique and body position of the performance of an exercise
Difficulty Score (D Score)	Score of the content of an exercise, determined by the addition of the DV of the elements, the CV and the EG Requirements Values
Connection Values (CV)	Score of the combination between two elements
Neutral Deductions (ND)	Deductions for specific composition rules not respected in an exercise

1.Introduction

Gymnastics has captured the public's interest in several competitions due to its graceful and technically demanding performances (Xu and Jia, 2022). Artistic gymnastics is a very demanding discipline requiring motor coordination and athletic training. Less well known is its management complexity. Competitions are generally held in teams, with each athlete competing on different equipment, presenting the judges with sequences of movements of varying difficulty. These movements (i.e., elements) are executed by gymnasts in a specific routine called "gymnastics exercise", which follows particular rules of composition (Lindhard, 2018). The syntactical correctness of exercise sequences is prescribed in the so-called Code of Points (COP, hereinafter) – the official competition manual drawn up by the International Gymnastics Federation. There is substantive evidence indicating that the COP wields a discernible influence over the trajectories of gymnasts' careers, imparting both positive and negative effects that extend to the shaping of their training routines (Carrara and Mochizuki, 2011). The strategic composition of an optimal gymnastics' routine holds the potential to be a decisive factor in determining the success of individual athletes and entire teams (Myrian et al., 2019). Despite the paramount importance of the COP in this context, its current manifestation as a .pdf manual poses a significant challenge in terms of accessibility. Such accessibility issue has on various occasions hindered the judicious assessment of the validity and intrinsic value of specific exercises, both by team managers and referees (Flessas et al., 2014). The multifaceted impact of the COP on gymnastic careers underscores the imperative of its accessibility and comprehensibility. In navigating the intricacies of gymnastics training and performance, coaches, athletes, and judges alike grapple with the need for an expedient and user-friendly reference tool, since the current .pdf format, not only imposes logistical hurdles but also diminishes the potential for a full understanding of the knowledge embedded in the COP. It exists an exigency to explore and implement innovative formats or artefacts (e.g., knowledge graphs) that might enhance the ease of access and assimilation of the COP, thereby fostering a more informed and equitable evaluation of gymnastic routines. The article presents a cutting-edge software tailored for the intricate realm of artistic gymnastics evaluations – namely LEVERAGE (i.e., to use (something) to maximum advantage). The LEVERAGE software has been successfully implemented and is currently in use by the artistic gymnastics team Spes Mestre. This real-world application has allowed for practical testing and validation, demonstrating the tool's effectiveness in managing and evaluating gymnastics routines. However, the implications of this innovation reach far beyond the gymnasium. The use of knowledge graphs as versatile artifacts demonstrated their applicability in an array of knowledge domains (De Nicola et al., 2022; Falegnami et al., 2021, 2022; Garito et al., 2023; A. Tomassi et al., 2024) allowing for reducing information related complexities such as information overload throughout the simplexity paradigm (Falegnami et al., 2024; Patriarca et al., 2019). With potential applications spanning virtually all fields of knowledge, these tools offer a transformative solution for bridging the gap between intricate data and effective management, enhancing our understanding of simplexity across diverse sport disciplines (Wang et al., 2017).

2. Gymnastics competitions' rules

During gymnastics competitions every exercise performed is evaluated by two different types of juries, which apply standardized rules of scoring (also included in the COP). The D-jury determine the Difficulty Score (D Score), the content of an exercise, and the E-jury the Execution Score (E Score), the technique and body position of the performance (Heiniger and Mercier, 2021). In particular, the D Score of an exercise is unique and objective, because each element has its own Difficulty Value in agreement with the Table of Elements of the COP (Bradshaw et al., 2016). The Final Score of an exercise, which makes the ranking of the competition, is established by the addition of the D Score and the E Score. Generally, no change in score is allowed after the rating has been flashed on the score board, except in case of an inquiry. In fact, the coach is guaranteed the right to inquire to Superior Jury concerning the evaluation of the content (D Score) of the exercise of the gymnast (Heiniger and Mercier, 2021). The reason why inquiries are admitted is the possibility of mistakes on D Score by the jury, because of the great amount and complexity of the Table of Elements and the composition rules of the COP. To illustrate the complexity of the scoring system, it should be noted that gymnasts can perform over 800 different elements in competitions, all included in the latest version of Men's COP. All elements are classified in different tables according to their own individual properties, which make each element unique. To date, when dealing with complex issues, the extent of these challenges depends on one's experience. Young coaches, typically unfamiliar with COP, are particularly prone to errors when preparing the routines for their gymnasts, resulting in unallowed sequences. These syntax errors are often discovered only after the score has been flashed on the score board.

3. Comparison with existing alternatives to Leverage

Due to reduced visibility of gymnastics in comparison to other richer sports (e.g., basketball, football), many gymnastics federations are low on budget (Desbordes, 2006), resulting in less coaches than needed: often the same person coaches gymnasts at different ages and technical levels, with specific regulations. The resulting information overload is becoming a major issue for gymnastics professionalism. In order to manage effectively all this knowledge, some software applications have been

commissioned, for example, by National Gymnastics Federations (i.e., 3D Gym Men by the French Gymnastics Federation). Other different software tools have been developed by third parts as well. HelpGym, Gym Art, Routiner, GymTrack World are the most relevant tools already available in the realm of gymnastics, whose most significative features are a digital version of the COP and a management section for gymnasts and exercises, similar in the intentions to the LEVERAGE's counterparts. With the aim of proving the superiority of the proposed solution, LEVERAGE has been benchmarked, by every feature offered, to its competitors (Table 1).

First of all, users need a subscription fee account to use all the features, otherwise these applications work with limitations. Moreover, even if they claim the same functionalities, when tested, these tools got wrong in some specific tasks, such as the calculation of routines on Pommel Horse, not permitting to include performable elements or permitting to build without warnings not allowed combinations.

Table 1: Features and functionalities included in other existing software compared to Leverage

EXISTING SOFTWARE	Digital Consultation of the COP				Management of Gymnastics Entities				Exercise Scoring	
	Elements	Filter Buttons	Search Buttons	Rules	Gymnasts	Teams	Results	Exercises	Score Calculation	Validity Check
GYMES	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
3D GYM MEN	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗
GYM ART	✓	✓	✓	✓	✓	✗	✗	✓	✓	⚠
HELPGYM	✗	✗	✗	✗	✓	✗	✓	✓	✓	⚠
ROUTINER	✗	✗	✗	✗	✓	✓	✗	✓	✓	⚠
MEN'S SKILLS BY ROUTINER	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗
GYMTRACK WORLD	✓	✓	✓	✗	✗	✗	✓	✓	✓	⚠
LEVERAGE	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Legend

Icon	Definition
✗	Functionality not included
✓	Functionality included for free
✓	Functionality included only for subscription fee accounts
⚠	Functionality included but wrong in some specific tasks

4. Main modules of LEVERAGE

LEVERAGE relies upon four main modules detailed in the following sections:

4.1 Environment and COP as a knowledge graph

To keep the development costs contained and the final product open to the gymnastics community, LEVERAGE was developed as a custom add-in for Obsidian, a well-known personal knowledge management solution (Obsidian, 2020). Obsidian natively offers a framework of connectable Markdown files (i.e., notes), each of which can be assigned with specific properties. The resulting structure, for a humorous coincidence, is called a vault. A well-formed vault can be visualized, explored as graph (Figure 1), and queried leveraging regular expressions. Obsidian's potential can be easily expanded by installing official plugins or those ones developed by third parts (i.e., community plugins).

As a consequence of this flexibility, the first module was realized translating the latest version of Men's COP in an Obsidian vault. The implicit taxonomy underlying the Table of Elements of the COP was used as a reference for structuring its Markdown (MD) counterpart. However, a first thorough revision of the COP was necessary before its implementation in LEVERAGE to amend the inconsistencies discovered during the process (i.e., some elements were missing). All the discovered missing elements (and their corresponding icons) were designed ex-nihilo to make the COP consistent and ready for the full plugin functionality.

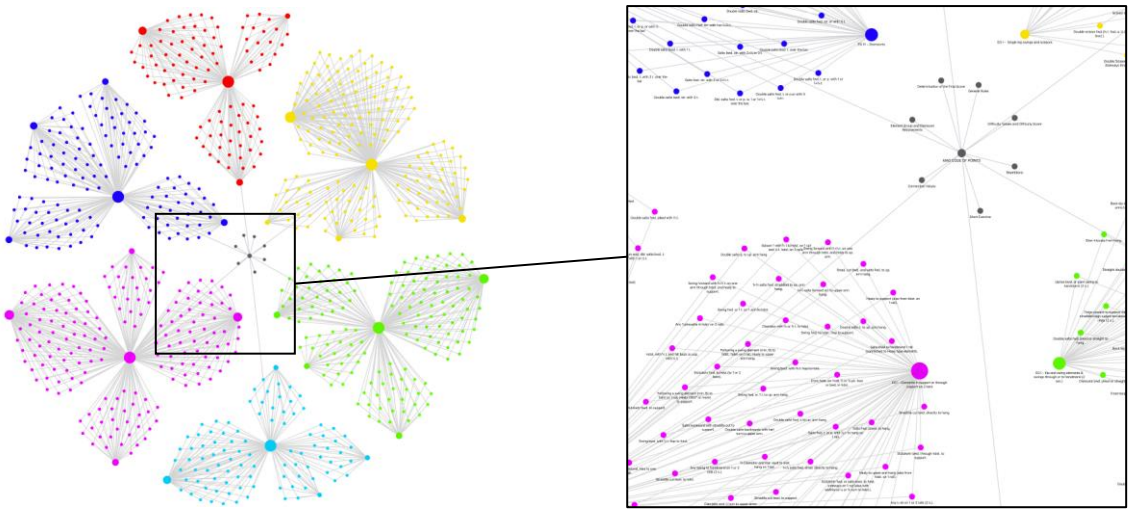

Figure 1: Knowledge graph of Men's COP, structured on the implicit taxonomy underlying the Table of Elements.

4.2 The Elements Database

The COP content was extracted and then translated into its vault counterpart. Each gymnastic element symbolic depiction followed the hierarchy given by Apparatus/EG/Code Identification Number, therefore, all images and symbols were imported in Obsidian and organized through hierarchically ordered folders. These folders contain notes reporting all the distinct properties of an element - e.g., name, originator's name, image, symbol, code identification number, apparatus, element group (EG), difficulty value (DV). Finally, all exercise composition rules of the COP were collected in specific MD files and included in an "EXERCISES RULES" named folder.

Notably, some elements performable on Pommel Horse (i.e., circle with handstands, flops, combined elements, dismounts) were accepted by the international regulation but not already reported in the Table of Elements. Therefore, taking care of the prescriptions included in the Men's Symbology Document of the Fédération Internationale de Gymnastique, they have been completely designed from scratch tracing the style adopted by the COP and included in Obsidian as MD files (Figure 2).

Once all element files were created and hierarchically ordered in their specific folders, the Database of Elements "MAG COP DB" was created. Each column of this database shows a specific element property included in its Metadata. All element files included in the database were also ordered by Apparatus, EG and Code Identification Number, following the order used in the Table of Elements of the COP (Figure 3).

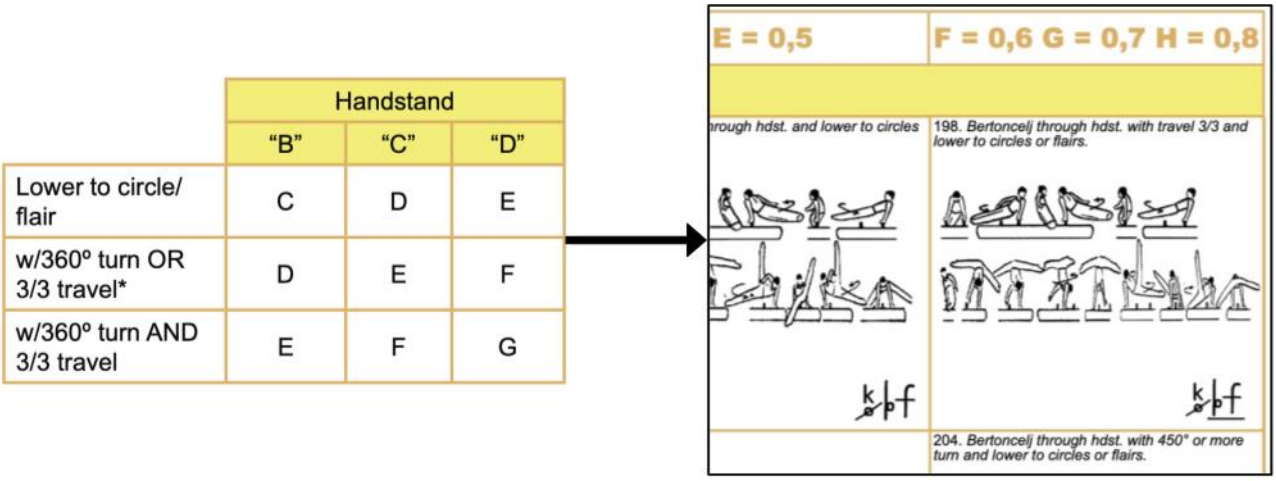

Figure 2: Design of the Table of Elements not reported tracing the regulation section of the COP.

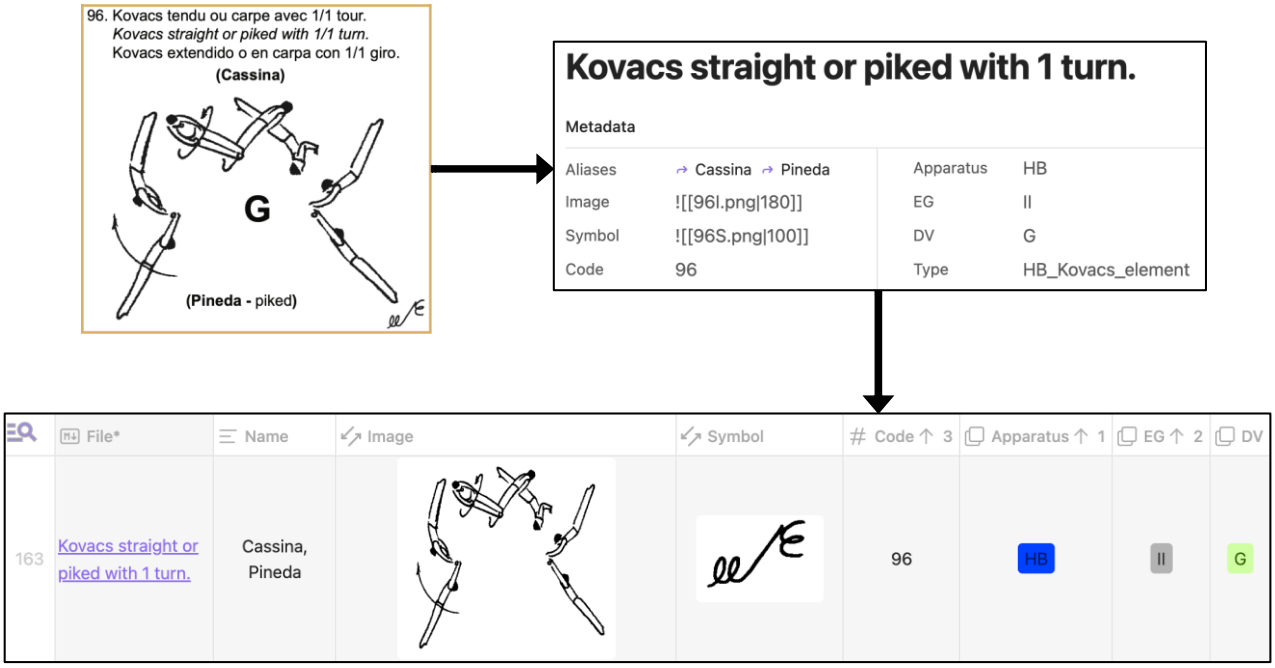

Figure 3: Extraction and translation of elements from the COP to MD files included in the Database of Elements.

4.3 The User-Management Database

Four new empty databases were built: **Gymnasts DB**, profiling athletes; **Results DB**, collecting results information per athlete; **Teams DB**, letting athletes to be grouped by different sets (i.e., teams); **Exercises DB**, representing information of a gymnastics exercise: the 9 elements performed, the dismount, the Difficulty Score (D Score) and the Connection Values (CV). In particular, the 10 elements columns (9+Dismount) were related to the "MAG COP DB", in order to allow the user to directly choose the element from the Database of Elements.

These databases allow to connect different types of files through common properties. In this way, a fully functioning automatically updated RDBMS is implemented. Each element of new exercise files is automatically included through the Internal Link to the original element file. This allowed the construction of exercises' routines per gymnast, per team.

4.4 The Gymnastics Plugin

This brand-new plugin was coded in TypeScript and can be imported in Obsidian. This is the specific module designed to "Check a gymnastics exercise". When a user makes a general mistake, this module immediately alerts them. Otherwise, the algorithm moves forward with the exercise. COP rules were sorted inductively, first checking

general composition rules, and then apparatus and connection rules.

5. Methods used in LEVERAGE development

To develop LEVERAGE, we engaged with coaches, judges, and gymnasts to understand their needs and challenges with the current PDF-based Code of Points (COP). We analyzed existing tools to identify gaps and areas for improvement. Based on this research, we selected Obsidian for its flexibility in handling connectable Markdown files, enabling the creation of an interactive and queryable knowledge graph (Tomassi et al., 2024). We translated the latest Men's COP into a structured Obsidian vault, addressing inconsistencies and ensuring completeness. We designed the RDBMS to manage entities such as gymnasts, teams, exercises, and results, integrating these into the knowledge graph to enhance knowledge management and accessibility.

A custom plugin in TypeScript was developed to check gymnastics exercises against COP rules, ensuring accurate difficulty score calculations and validation of exercise sequences. Extensive beta testing and user feedback helped refine the tool. For the state-of-the-art analysis, we reviewed academic literature and industry reports to align our tool with official standards.

This comprehensive approach ensured that LEVERAGE is a robust, user-centric solution for managing the complexities of artistic gymnastics.

6. Conclusions

LEVERAGE has the potential to be a crucial ally for those managing, coordinating gymnastics teams, and scoring performances. Unlike other existing solutions, LEVERAGE encompasses all necessary tools in a single, free platform. The revision of the COP, digitalization for interactive consultation, and a robust management system contribute to improved gymnastic entity management. The plugin's capabilities further reduce errors in D Score calculation and enhance exercise planning for coaches.

Through a thorough revision of the Table of Elements, correcting symbols, and introducing new elements, the software makes a significant contribution to international regulations. The availability of a dedicated .pdf file in the Documents Section further facilitates access and reference for users. The Digital COP simplifies the consultation of gymnastic rules. Interactive links and a hierarchical structure ease the transition between general exercise rules and specific rules for apparatus. The Gymnastics Management System offers a sophisticated DBMS dedicated to gymnastic entities. Coaches can efficiently manage gymnasts and teams, with real-time updates and customizable properties. The export/import functionality improves data portability, allowing users to work with information outside the software environment. Through an advanced algorithm for exercise analysis, calculating Difficulty Scores (D Score), Connection Values (CV), and detecting errors in composition, it provides a powerful tool for exercise construction. The seamless integration of plugin-generated data into Metadata and relevant databases ensures a holistic approach to exercise management.

At the moment LEVERAGE has been deployed according only to the men's version of the COP. This limits its applicability to more general competitions contexts.

LEVERAGE significantly contributes to the theoretical landscape by introducing a novel approach to managing gymnastics regulations through a knowledge graph framework and relational databases. This innovation enhances the accessibility and understanding of the Code of Points (COP), facilitating more accurate exercise planning and evaluation. Its successful implementation with the Spes Mestre team demonstrates its practical applicability and potential for broader adoption, advancing both theoretical and practical knowledge in sports management.

Looking ahead, the groundwork laid by LEVERAGE opens avenues for future developments, such as more sophisticated analyses and probabilistic assessments, promising continuous improvement in the field of gymnastics management. The role of software and technology in simplifying complexity and enhancing knowledge management is pivotal for advancing solutions across various domains.

Acknowledgments

LEVERAGE is freely available at GitHub: https://github.com/patronstefano/LEVERAGE .

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