The Relevance of Nature-Inspired Metaheuristic Algorithms in Smart Sport Training

Iztok Fister Jr.(✉)

Faculty of Electrical Engineering and Computer Science, University of Maribor, Koroška cesta 46, 2000 Maribor, Slovenia
iztok.fister1@um.si

Abstract. The main contribution of this paper is to show the linkage between the domains of Smart Sport Training and Nature-Inspired Metaheuristic Algorithms. Every year, the Smart Sport Training domain is becoming more and more crowded by different intelligent solutions that help, support and encourage people in maintaining their healthy lifestyle, as well as their sporting activities. On the other hand, nature-inspired algorithms are powerful methods for solving different kinds of optimization problems. In this paper, we show the applicability of nature-inspired algorithms in solving different intelligent tasks in the domain of Smart Sport Training. Recent progress and selected applications are outlined systematically, and the current implications of these developments are substantiated by their real usage.

Keywords: Artificial Sport Trainer · Nature-inspired algorithms · Health and fitness · Smart Sport Training · Optimization

1 Introduction

This paper corresponds with the talk that I gave at the International Conference On Emerging Applications & Technologies for Industry 4.0 (EATI) 2020. The paper is split into two parts. The first part of this paper is devoted to the foundations of nature-inspired metaheuristic algorithms and their challenges, while the second part is devoted to the description and examples of practical use of nature-inspired metaheuristic algorithms in the domain of Smart Sport Training (SST) [10,23].

In recent years, we have made effort to propose a digital twin that would have similar abilities as a human sport trainer. We named this solution Artificial Sport Trainer, or, simply, AST [10]. AST is based on computational intelligence methods [7], where nature-inspired metaheuristics play the most crucial role among the other computational intelligence methods [7], e.g. fuzzy systems. After a few years of AST design and development, AST is now a collection of smaller units (building blocks), where each one covers an aspect of sport training, i.e.

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planning the sport training sessions, meal planning or injury prevention. These building blocks are linked and integrated with each other in order to simulate the abilities of a human sport trainer. Loosely speaking, the strongest confident argument for the adoption of AST is that AST makes decisions solely based on data. Therefore, AST tends to be fully autonomous and not tailored to a specific group of athletes.

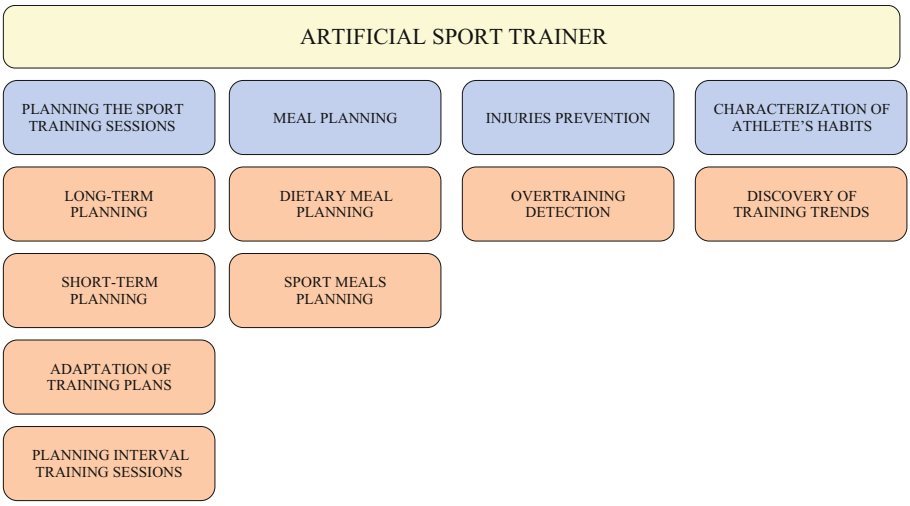

Fig. 1. Artificial Sport Trainer in a nutshell.

Figure 1 depicts the current functionalities that are supported in AST. In the current state of the AST, the majority of the emphasis is given to the planning of sport training sessions, as well as meal planning. Nevertheless, new functionalities are still under heavy development and, therefore, more aspects of training are planned for future integration with existing AST functionalities.

AST is just one example of a more complete intelligent system in sport that is mostly based on nature-inspired metaheuristics. There are many different applications using nature-inspired algorithms in sport, but they do not offer a comprehensive view of sports training such as AST. In other words, most of the applications cover only one aspect of sport training.

In the continuation of this article, in Sect. 2, a short overview of nature-inspired algorithms is provided, while Sect. 3 outlines the features of smart sport training as well as, some of the selected applications of nature-inspired metaheuristics in the SST domain. In Sect. 4 the transition of knowledge from research papers to the real-world is discussed using a real example. The paper is concluded with a summary in Sect. 5.

2 Nature-Inspired Metaheuristic Algorithms

Nature frequently serves as an inspiration to researchers in the development of new metaheuristic algorithms. These computer algorithms mimic the particular behavior of some fascinating behaviors of different animal species, natural evolution, physics and chemistry-based phenomena, sport and also sociological phenomena respectively [2]. The main members of this family of algorithms are: Evolutionary Algorithms (EA) [6] and Swarm Intelligence Algorithms [3]. Although many sub-members exist in each group, what all algorithms have in common is that they consist of the initial population which undergoes to the variation operators that are specific for the particular algorithm. After the modification of a population using the variation operators, the fittest members of the population are then selected for the next generation. A very approximate and unified algorithmic presentation of a nature-inspired metaheuristic algorithm is presented in Algorithm 1.

Algorithm 1. Simple nature-inspired metaheuristic algorithm.

```
INITIALIZE_population_with_random_candidates;
EVALUATE_each_candidate;
while TERMINATION_CONDITION_not_met do
    MODIFY_candidates_using_specific_variation_operators;
    EVALUATE_modified_candidates;
    SELECT_candidates_for_the_next_generation;
end while
```

Despite the age of this research area, there is still a lack of universal taxonomy which would group all nature-inspired metaheuristic algorithms in exact groups, either by the inspiration or principle of their architecture. There are some efforts [16,21] that propose some classification/taxonomies but the whole research community has not yet accepted any final taxonomy.

Finally, it should be noted that the entire research area has also had some dark moments. The infinitely large pool of possibilities for using algorithms in various applications, has consequently, encouraged researchers to develop new algorithms that can also be presented as nature-inspired metaheuristic algorithms. After the year 2000, the number of new algorithms increased drastically (see Fig. 2)[1]. Usually, these "new/novel" algorithms mimic the selected inspiration or metaphor from nature (a particular biological or physical system), whereby the authors have hidden their internal operation under the description of the inspired system's behavior. Numerous research papers (some of them [14,22,24]) have raised questions about the uniqueness and true scientific value of these newly created algorithms.

[1] References taken from https://github.com/fcampelo/EC-Bestiary. Only references with a valid DOI were considered in this study.

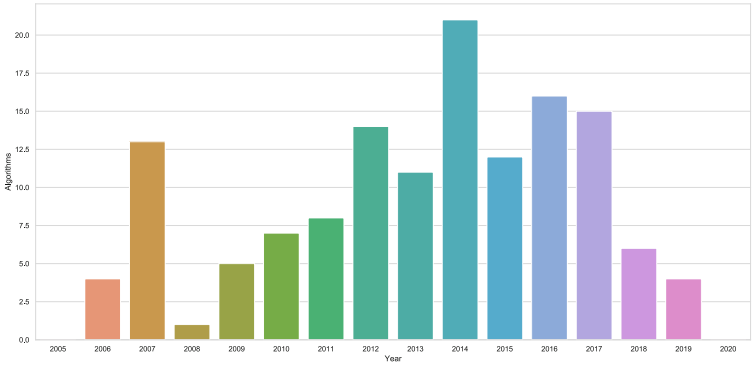

Fig. 2. The emergence of new nature-inspired algorithms.

3 Smart Sport Training

Smart Sport Training is a type of sports training, which utilizes the use of wearables, sensors, and Internet of Things (IoT) devices, and/or intelligent data analysis methods and tools to improve training performance and/or reduce a workload, while maintaining the same or better training performance [23]. SST is not a very old field of research, but, according to Fig. 3[2], it has been gaining in popularity in recent years. One of the main implications of this is the rapid development of mobile and ubiquitous computing, which makes it easy to track and monitor data during sports activities on the one hand, and on the other hand, the development of different intelligent data analysis methods. Intelligent data analysis methods allow us to make different predictions in individual and team sports, search for hidden knowledge in large databases of sport performances, make sport more sociable, and recommend appropriate training for an athlete that is based on either his/her existing trainings, or is created from scratch.

3.1 Applications of Nature-Inspired Metaheuristics in Smart Sport Training

One of the advances of nature-inspired metaheuristic algorithms is that they can easily be used in areas where there is a lack of domain-specific knowledge about the problem to be solved. Many problems in the domain of sport are of that kind. The added value of these algorithms is also their easy integration in support systems for decision-making, while these methods are also very scalable, yet offer the possibility of easy parallelization.

[2] * on Fig. 3 denotes the current year that is still in progress. Therefore, the number of research works is not final.

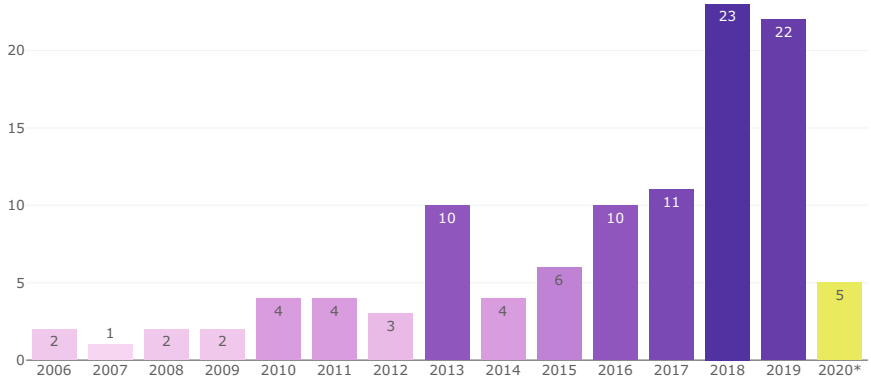

Fig. 3. AI in sport according to the years

The domain of SST is very wide. On the one hand it represents different sports, while, on the other hand, it represents many hard problems that can be solved by the use of nature-inspired metaheuristic algorithms. Table 1 presents some selected examples of SST applications that are based on nature-inspired metaheuristics besides the AST that was presented in the previous sections.

Table 1. Some selected applications of nature-inspired algorithms in SST.

Applications of nature-inspired algorithms in different sports		
Cricket	Cricket team selection	[1]
Cycling	Planning the training sessions	[10, 19]
	Diet planning	[8]
	Characteristics mining	[11]
Football	Planning	[5]
Running	Performance analysis	[12]
	Planning the optimum running speed	[4]
Soccer	Simulation of soccer kicks	[18]
Triathlon	Planning training sessions	[9]

According to Table 1, nature-inspired metaheuristics can be used for SST applications in individual sports (cycling, running, triathlon as an example) as well as in team sports (cricket, football, soccer as an example). However, current research trends [23] show more research directed towards the individual sports, presumably due to the easier control of individual athletes in experiments as well as easier data collection in individual sports (see the example of a cycling dataset [15]).

4 Transition of Knowledge from Research to the Real-World

There is no doubt that researchers in the research area that link metaheuristics and the SST domains have produced a lot of valuable work in recent years. However, there is a real question of how many of the applications presented in research papers are deployed in the real-world. Most of the research that was presented until recently were ideas and prototypes [23]. Interestingly, only a few works reported some validation-level results in a real environment. We suspect that the flow of knowledge produced through research is slowly entering the real world [23] due to many barriers, including the insensitivity of coaches in the use of computer support or in obtaining the consent of athletes who could test new methods in their sport training.

Fig. 4. An example of a real-world application (a) GUI application (b) Smart watch (c) Bike settled on a Tacx trainer

Figure 4 depicts an example of knowledge transfer from research ideas/prototypes to practical use. The ideas of automatic interval planning [13] and adaptation of sport training plans [17] were applied for the realization of training of cyclists. Firstly, the proposed training plan was generated and later an initial training plan was adapted according to the performances of cyclists. In order to effectively validate the proposed ideas, a GUI application (Fig. 4a) was developed. The GUI application interacts with the cyclist on the one hand, while also showing the cyclist's heart rate in real-time, which is transmitted to a computer from a smart watch (Fig. 4b) via ANT+ protocol [20]. The cyclist's bike is settled on a Tacx trainer[3]. Heart rate data is stored each second, and after each interval is finished, the algorithm adapts the training for all subsequent intervals.

[3] https://tacx.com/.

A practical evaluation of the proposed solution revealed three important findings:

- The sport trainer was able to gather more insights and characteristics of his/her athletes when training intervals.
- The overall training was more dynamic, because each next training load of an interval was determined according to the previous intervals.
- Cyclists performed the whole training session of the same or even better quality as if they were training without this solution.

5 Conclusion

This paper briefly presented the interplay between nature-inspired metaheuristic algorithms and their use in SST. The SST domain is now becoming very popular within the research community. Additionally, the whole research area also has considerable backing in the real-world, since sport is one of the biggest businesses around, and therefore open to technological ideas. On the other hand, the connection of SST in the support of a healthy lifestyle is also an important mission for this research. For the future, there are still a plenty of challenges. Firstly, there are a lot of sports with no research in the domain of SST, which means there are many potential possibilities for future research. Secondly, the most important thing would be to ensure the quick flow of ideas in research papers into the real world. Last, but not least, obtaining test datasets and their dissemination in order to allow the easier replication of published results also remains an important cornerstone for the future of this area.

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