Computational Intelligence and Smart Sport Training

Lecture Series on Applications and Theory of Nature-Inspired Intelligent Computing

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Agenda

PART 1:

- A brief outline of population-based nature-inspired algorithms
- Evolutionary algorithms and swarm intelligence
- Software tools

PART 2:

- A brief outline of Smart Sport training (SST)
- Selected applications of nature-inspired metaheuristic algorithms in sport
- Outline of Artificial sport trainer
- Future paths of computational intelligence in sports

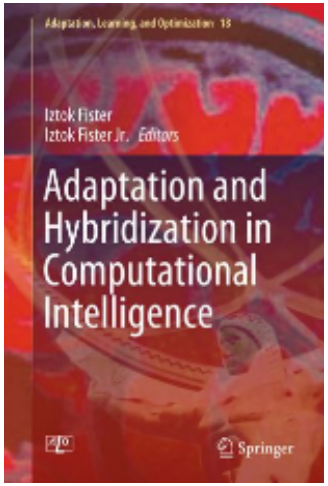
Whoami

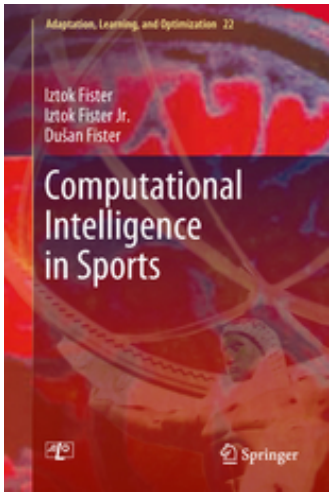
- My institution: Faculty of Electrical Engineering and Computer Science at the University of Maribor, Slovenia
- Main research interests: Artificial Intelligence, Data Mining, Sport Science

Other semi-pro interests: Triathlon, running, climbing

More info: `www.iztok.xyz`

Selected works





- Member of several conference program committees
- Associate Editor in Expert Systems with Applications journal

Background

- Stochastic population-based nature-inspired metaheuristics:
  - Evolutionary Algorithms (EA) - Darwinian evolutionary theory,
  - Swarm Intelligence (SI) - behavior of social insects.
- EA's and SI's methods are basically intended for optimization tasks (continuous and discrete).
- All methods offer enormous possibilities for solving the real-world problems.
- Stochastic population-based nature-inspired algorithms are also used by major players in IT fields.

Inspirations of nature-inspired metaheuristics

- Nature serves as an inspiration in the development of metaheuristic algorithms.
- These computer algorithms mimic the behavior of some fascinating behaviors of:
  - different animal species,
  - natural evolution,
  - physics and chemistry-based phenomena,
  - sport, etc. [Fister Jr. et al., 2013]

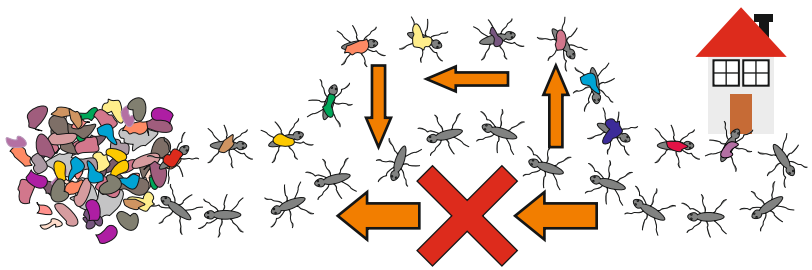
More about inspirations: A Brief Review of Nature-Inspired Algorithms for Optimization,
`https://arxiv.org/abs/1307.4186`

Evolutionary algorithms

- EA's are inspired by Darwinian evolutionary theory of the survival of the fittest.
- Main operators: selection, crossover, mutation.
- Many variants of EA's have been proposed in literature, i.e. Genetic algorithms, Genetic programming, Differential evolution, Evolutionary programming.

Swarm intelligence algorithms 1/2

- Swarm intelligence (SI) concerns the collective, emerging behavior of multiple, interacting agents who follow some simple rules.
- While each agent may be considered as unintelligent, the whole system of the multiple agents may show some self-organization behavior and thus can behave like some sort of collective intelligence.



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https://dk.um.si/IzpisGradiva.php?id=67392

Swarm intelligence algorithms 2/2

Some representative members of SI algorithms are:

- Ant colony optimization (ACO)
- Particle swarm optimization (PSO)
- Artificial bee colony (ABC)
- Firefly algorithm (FA)
- Cuckoo search (CS)

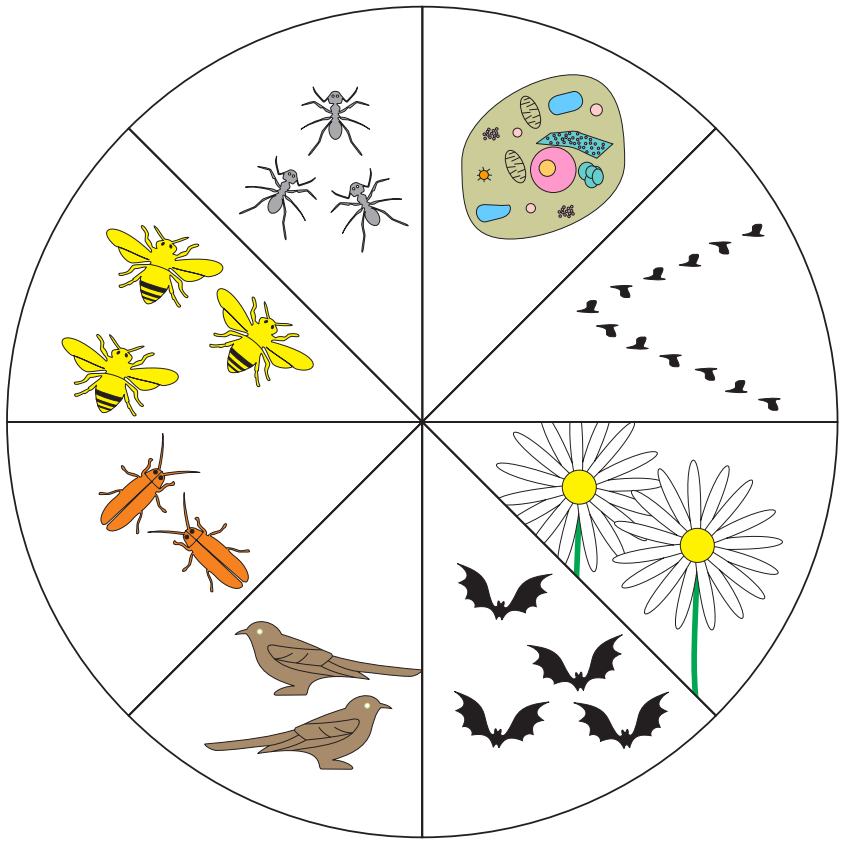
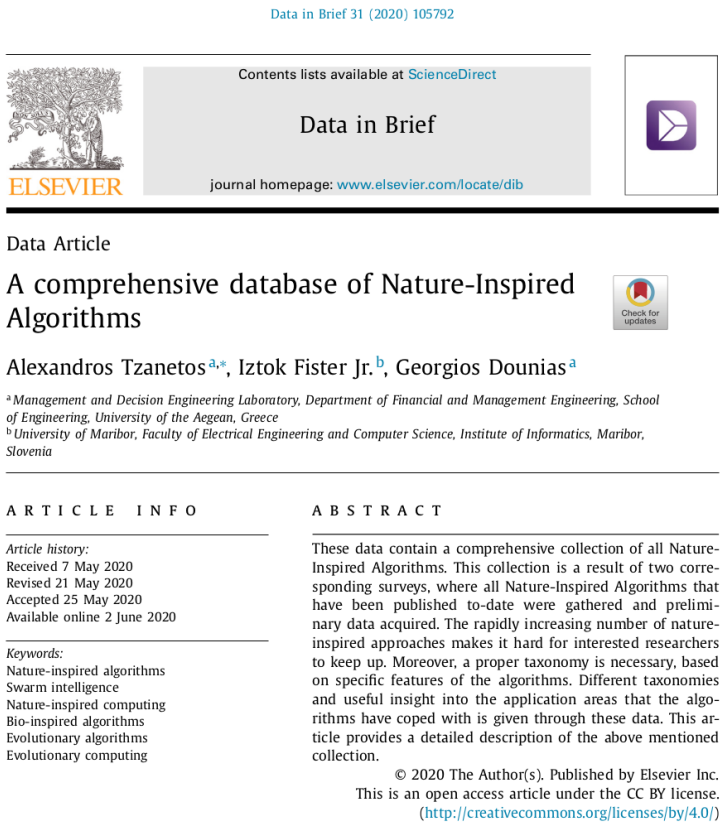


Image source:
https://github.com/firefly-cpp/figures

How many nature-inspired metaheuristics exist?

- It is hard to estimate the number (probably more than 500).
- Catalogues of algorithms exist, but do not cover all algorithms.
- Unfortunately, the number is increasing every year.



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Data Article

A comprehensive database of Nature-Inspired Algorithms

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ABSTRACT

These data contain a comprehensive collection of all Nature-Inspired Algorithms. This collection is a result of two corresponding surveys, where all Nature-Inspired Algorithms that have been published to-date were gathered and preliminary data acquired. The rapidly increasing number of nature-inspired approaches makes it hard for interested researchers to keep up. Moreover, a proper taxonomy is necessary, based on specific features of the algorithms. Different taxonomies and useful insight into the application areas that the algorithms have coped with is given through these data. This article provides a detailed description of the above mentioned collection.

Image source:
https://doi.org/10.1016/j.dib.2020.105792

NiaPy framework

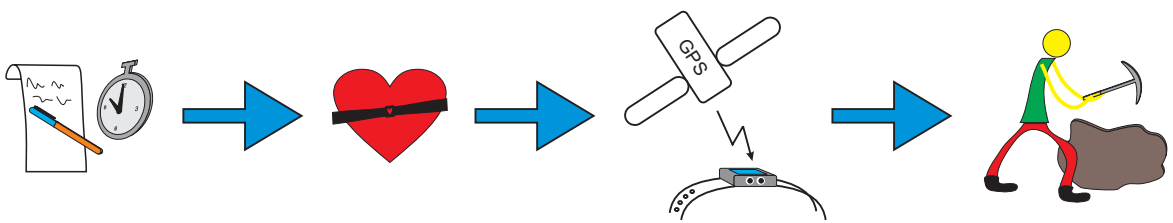
- Python microframework for building nature-inspired algorithms
- Written in pure Python
- Goals:
  - To provide clean implementation, good documentation and examples
  - Allow researchers to study the mechanisms of various algorithms
  - Intended for use in industry
- Free software (free to use in commercial applications and in academia)
- Install/Download: https://github.com/NiaOrg/NiaPy

Smart Sport Training

- Nowadays, in the field of sports, there are rare IT solutions that are capable of planning sports training.
- Even rarer solutions achieve similar quality in planning sports training as a real trainer.
- With the development of smart devices (phones, smartwatches), there is a possibility of obtaining training data.
- Main motivation: processing this data for sports training needs.

Sports training

- A complicated and complex process based on scientific and pedagogical principles.
- Goal: to systematically compose training in such a way as to achieve a top result within the chosen discipline.
- The final effect of systematically composed training:
  - athlete's good form,
  - increased capacity of the athlete's organism.
- A problem that may arise in the sports training process:
  - overtraining.
- Especially beginner athletes need the help of sports coaches in sports training.
- Why not use computer technology in the field of sports training?



Solutions so far

- Solutions that can plan sports training based on analyzing existing activities are rare.
- Very few solutions explicitly use computational intelligence algorithms.
- Most solutions are based on artificial neural networks or fuzzy logic systems.
- Some examples:
  - pattern recognition with the help of ANN for evaluating the performance of exercises on trainers,
  - fuzzy logic for evaluating fitness training exercises,
  - combined approach of soft modeling and artificial immune systems in modeling sports training,
  - educational system AI-Virtual Trainer to help trainers.

See also: `https://github.com/firefly-cpp/awesome-computational-intelligence-in-sports`

Smart sport training

SST

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 (Rajšp and Fister, 2020).

Which sports are supported?

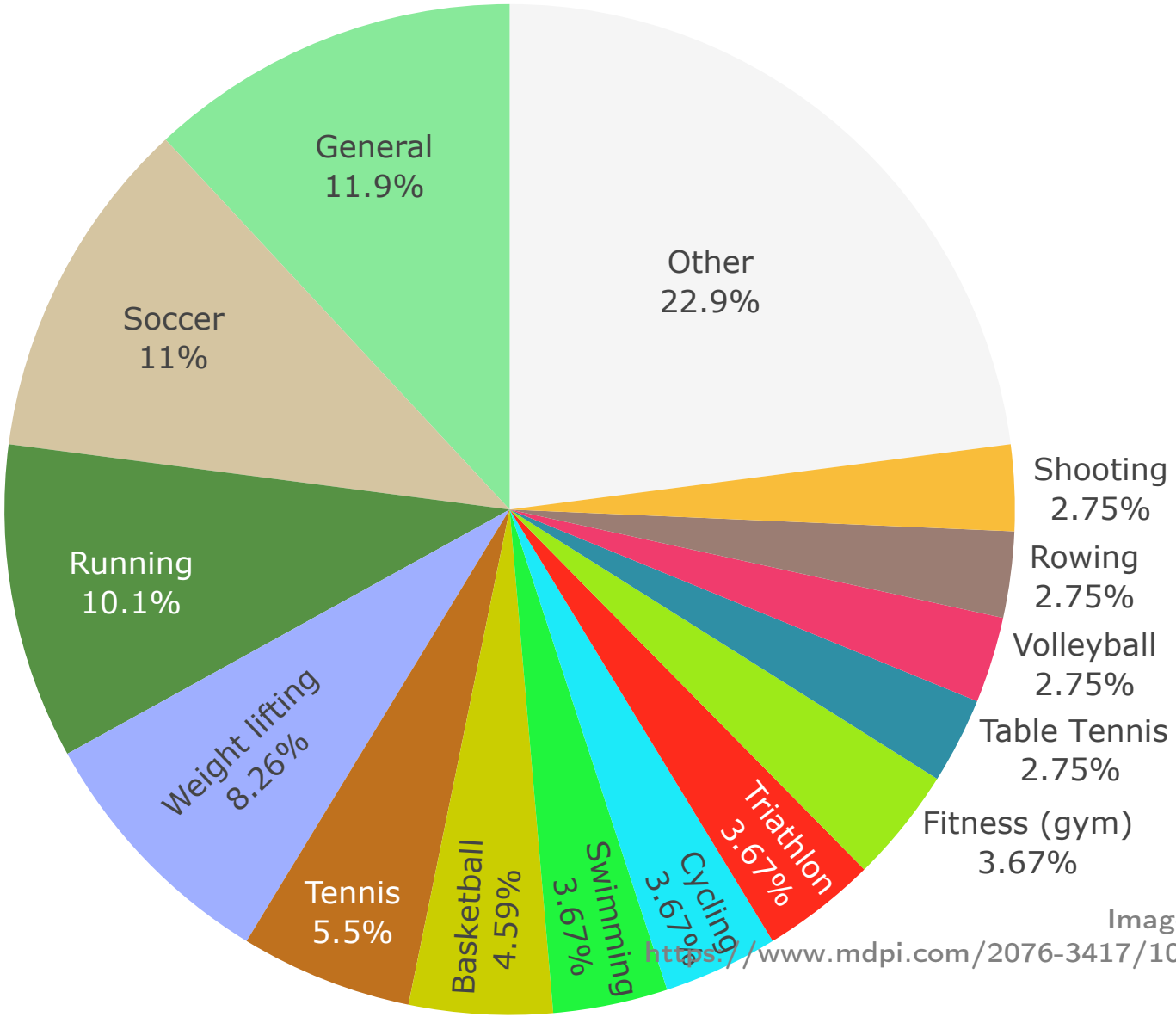


Image source:
https://www.mdpi.com/2076-3417/10/9/3013

Why sport is interesting venue for applications of nature-inspired metaheuristics?

- Abundant of data (sport trackers, sensors, health records) need to be processed.
- Data leads to a decision making.
- Many optimization problems (planning the sport training sessions, team selection).
- Other:
  - Target group: a lot of people all over the world.
  - Sport is a big business.
  - A huge connection with medicine.

Examples of some applications using nature-inspired metaheuristics

Applications of nature-inspired algorithms in different sports.		
Cricket	Cricket team selection	[Ahmed et al., 2011]
Cycling	Planning training sessions	[Fister et al., 2019a, Kumyaito et al., 2018]
	Diet planning	[Fister et al., 2016]
	Characteristics mining	[Fister et al., 2019b]
Football	Planning	[Connor et al., 2019]
Running	Performance analysis	[Fister Jr et al., 2017]
	Planning the optimum speed	[Brzostowski et al., 2013]
Soccer	Simulation of soccer kicks	[Khemka et al., 2005]
Triathlon	Planning training sessions	[Fister et al., 2018]

Our approach: Artificial Sport Trainer

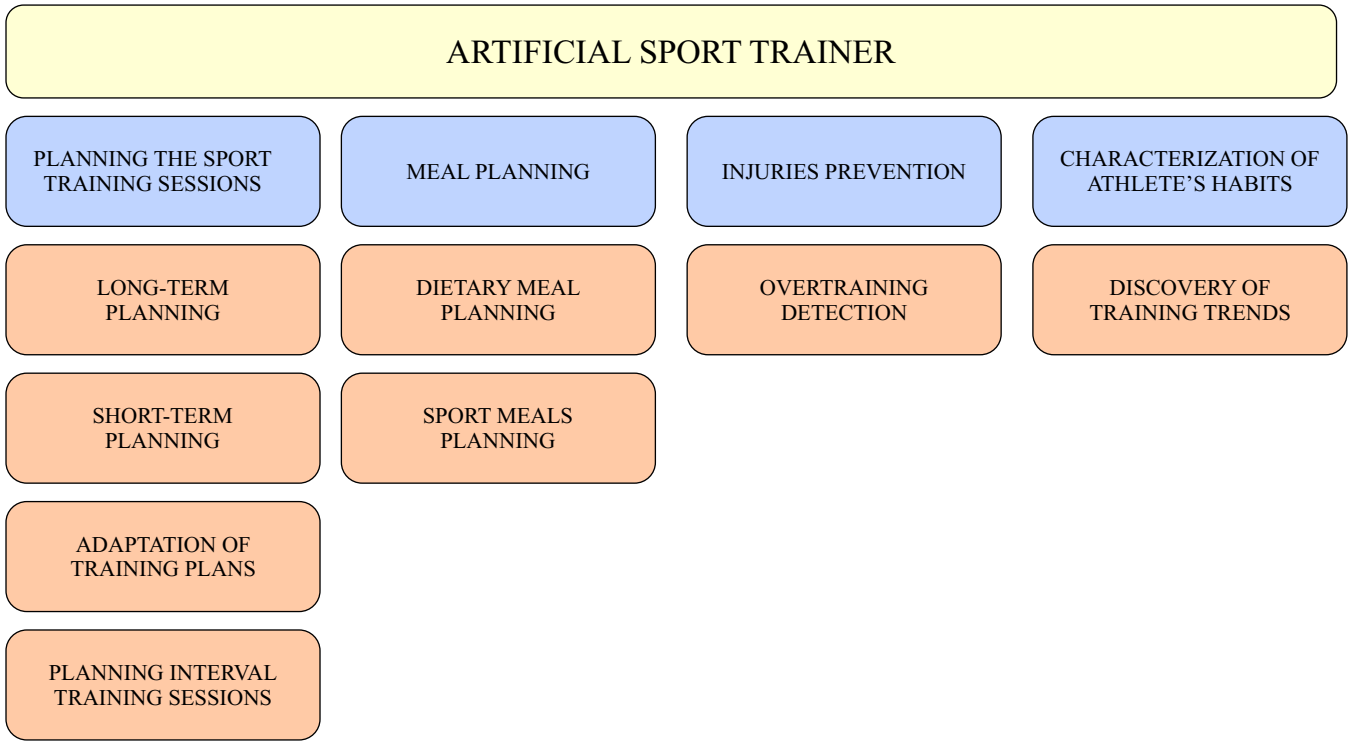


Figure: Schematic diagram of AST.

Features of Artificial Sport Trainer

- Extensible: new functionalities are easily to be added to existing functionalities.
- AST tends to be fully autonomous and not tailored to the specific group of athletes.
- AST can support different sports.
- The sport trainers are able to gather more insights and characteristics of his/her athletes when training.

Generating the sport training sessions using AST

Sport training plan that is generated by AST

Training sessions	*HR*	*TD*	TRIMP	Training sessions	*HR*	*TD*	TRIMP
1	142	65	9230	26	105	29	3045
2	156	64	9984	27	142	65	9230
3	141	91	12831	28	141	55	7755
4	125	38	4750	29	125	45	5625
5	141	74	10434	30	162	51	8262
6	158	47	7426	31	136	31	4216
7	128	36	4608	32	126	38	4788
8	128	26	3328	33	169	65	10985
9	142	65	9230	34	128	75	9600
10	141	55	7755	35	158	45	7110
11	141	91	12831	36	121	41	4961
12	115	28	3220	37	141	52	7332
13	142	65	9230	38	133	71	9443
14	158	51	8058	39	142	65	9230
15	129	45	5805	40	115	28	3220
16	125	45	5625	41	125	38	4750
17	128	75	9600	42	138	87	12006
18	142	65	9230	43	169	65	10985
19	132	29	3828	44	141	71	10011
20	115	28	3220	45	138	87	12006
21	125	29	3625	46	162	41	6642
22	141	87	12267	47	121	26	3146
23	141	55	7755	48	129	84	10836
24	128	75	9600	49	141	54	7614
25	157	65	10205	50	141	71	10011
Total	136.84	55.76	193675	Total	137.96	55.2	192809

An example of generated diet plan

Day	Breakfast			Break			Lunch			Break			Dinner			Total
	Food	[g]	[cal]	Food	[g]	[cal]	Food	[g]	[cal]	Food	[g]	[cal]	Food	[g]	[cal]	
1	Poached eggs Corn salad Yogurt Soya milk Avocados	56 149 245 200 150	126.05 36.89 163.37 66.00 325.74	Chocolate White grapes Cheese pies	22 100 -	130.28 76.43 388.61	Classic pizza Green salad	286 103	695.72 41.31	Kiwi Orange-Juice	180 248	84.04 116.24	Lens Coco-Pancakes	200 200	547.56 435.53	
Total			718.05			595.32			737.08			200.28			983.09	3,233.77
2	Almond Peach Oats-beverage	100 154 300	576.18 70.42 185.85	Chocolate White grapes Cheese pies	22 100 -	130.28 76.43 388.61	Thick soup Pork minced meat	- 250	120.30 697.50	Kiwi Orange-juice	180 248	84.04 116.24	Oats-beverage Chicken steak	300 300	185.85 536.97	
Total			832.45			595.32			817.80			200.28			722.82	3,168.67
3	Poached egg Corn salad Yogurt Soya milk Avocados	56 149 so245 200 150	126.05 36.89 163.37 66.00 325.74	Kiwi Orange Juice	180 248	84.04 116.24	Thick soup Pork minced	- 250	120.30 697.30	Cheese pies White grapes Chocolate	- 100 22	388.61 76.43 130.28	Cheese pies	-	388.61	
Total			718.05			200.28			817.8			595.32			388.61	2,720.06

Table: Diet plan

From lab to track

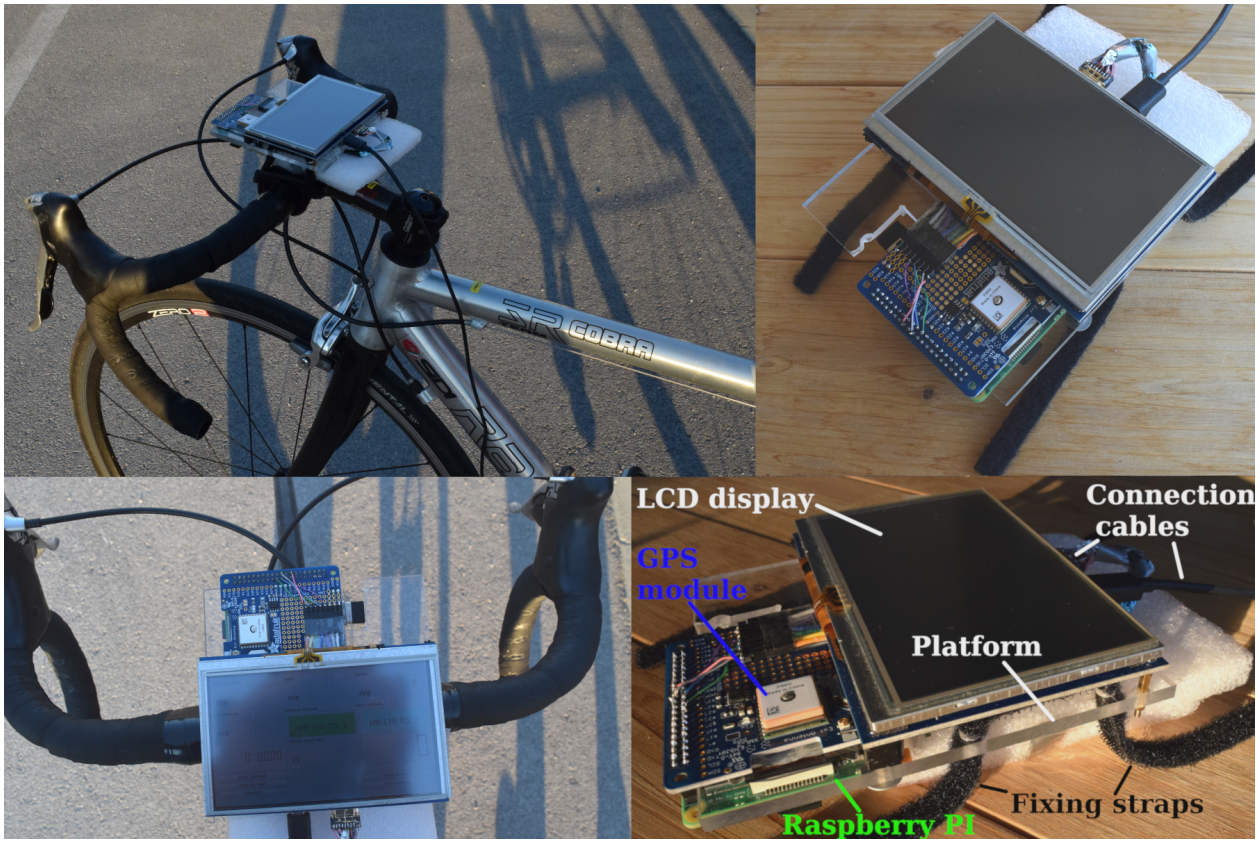


Image source:
https://arxiv.org/abs/2109.13334

Challenges in developing an artificial sports trainer

The main challenges we encountered during the development of the proposed solution:

- Acquisition of data: it is difficult to obtain real data of sports training. Many athletes hide them.
- Knowledge transfer and solution evaluation in the real world.
- Demanding software development.

What awaits us in the future

Challenges for the future:

- Planning of sports training with an emphasis on multi-disciplinary sports (triathlon, duathlon, aquathlon, etc.).
- Examining different options for artificial sports trainer extensions (e.g., injury prevention).
- Transferring the concept of an artificial trainer into practice (e.g., online application or integration with existing services).

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Questions and discussion