A 2020 TAXONOMY OF ALGORITHMS INSPIRED ON LIVING BEINGS BEHAVIOR

A PREPRINT

Luis M. Torres-Treviño
Posgrado en Ingeniería Eléctrica
Universidad Autónoma de Nuevo león
Ciudad Universitaria S/N, San Nicolás de los Garza, Nuevo León, México
luis.torrestrv@uanl.edu.mx

June 10, 2021

ABSTRACT

Taking the role of a computer naturalist, a journey is taken through bio inspired algorithms taking account on algorithms which are inspired on living being behaviors. A compilation of algorithms is made considering several reviews or surveys of bio-inspired heuristics and swarm intelligence until 2020 year. A classification is made considering kingdoms as used by biologists generating several branches for animalia, bacteria, plants, fungi and Protista to develop a taxonomy.

Keywords  Behavior of living beings · Bio inspired algorithms · Swarm intelligence

1 Introduction

Since the emerge of ideas about simulation of life in last decades, several algorithms have been proposed to solve complex problems inspired on nature phenomena; i.e. evolutionary computation or artificial life. A role of a naturalist or biologist is taken with the purpose for studying all living forms in a new ecosystem and trying to make a classification of all discoveries to form a taxonomy of living beings. This role is taken as a computer naturalist to make a compilation of algorithms inspired on behavior of living beings.

There are several bio-inspired algorithms; however, this work focus on actions of living beings like the growth of plants, reproduction of mushrooms, living of bacteria, the individuals behavior of animals, etc.; however, highlights the interactions between individuals of a group of different animals like school of fishes, flock of birds, herd of mammals, or swarm of insects.

Focusing on algorithms inspired in actions of living beings that belongs to any kingdom of the nature; nevertheless, it is important to locate all algorithms as possible. Only basic algorithms are considered, but derivations, variants and hybrids are omitted; at least, algorithms which involves an inspiration of any living being. Location of bio-inspired algorithms related with a specific species is made by a review of several papers of surveys which involve nature bio-inspired, swarm intelligence, and metaheuristics algorithms; however, several of these surveys consider different points of view.

It was consider only survey papers from ten years old ago because it is expected a more complete reviews since then. Surveys span in many cases all kind of algorithms; however many of them have been proposed recently; it maybe because the year 2020 is iconic. The most numerous surveys are related with nature inspired algorithms Agarwal and Mehta [2014], Siddique and Adeli [2015], Sindhuja et al. [2018], Krishnaveni [2019], Cuevas et al. [2020], Yang [2020], Sureka et al. [2020], Odili et al. [2018], or bio-inspired algorithms Binitha and Sathya [2012], Pazhaniraja et al. [2017], Amry and Al-Gaphari [2018], Del Ser et al. [2019]; specific swarm intelligence algorithms Parpinelli and Lopes [2011] and metaheuristics or population based algorithms Ruiz-Vanoyle et al. [2012], Xing and Gao [2019], Almufi [2019], Ma et al. [2019] Also, a review of applications of swarm intelligence has been made to establish more algorithms. Application of nature inspired algorithms can be found in several areas, not only optimization; however...

*https://www.uanl.mx/investigadores/luis-martin-torres-trevino/.
from all natural inspired algorithms, swarm intelligent are the most highlighted. Dynamic optimization [Mavrovouniotis et al. [2017]], Stock price prediction [Thakkar and Chaudhari [2020]], feature selection in big data [Nguyen et al. [2020]], Internet of things [Sun et al. [2020]], Deep learning [Darwish et al. [2020]], Automatic clustering [Ezugwu [2020]], VLSI routing problems [Chen et al. [2020]], and image enhancement [Dhal et al. [2019]]. Comparisons between different algorithms have been made in different works and focus on tests using state of the art benchmarks composed by test multidimensional functions and real problems [Bujok et al. [2019], Ma et al. [2017], Piotrowski et al. [2017], Pham and Castellani [2014]].

A review of different works about taxonomies was made considering papers which title has the word of taxonomy. Previous surveys includes taxonomies; however, mostly of them are a brief structures about algorithms, applications or inspirations. A complete set of taxonomies which shows different criteria of classification is made in Tzanetos and Dounias [2019] where it is presented natural inspired intelligent algorithms which focus on real world problems and applications like traveling salesman problems, operation research problems, energy problems, and other multiple applications. Taxonomy about memory usage, and a chronology in swarm intelligent metaheuristic algorithms was presented by Shaymah Akram Yasear and Ku Ruhana Ku-Mahamud Yasear [2019]. A complete set of taxonomies of natural and bio-inspired algorithms was presented by Molina et al. Molina et al. [2020] proposing several classifications like breeding behavior, flying, aquatics, terrestrial, and microorganisms animals. Also includes physics and chemistry based algorithms, social human behavior algorithms, plant based and a miscellaneous source of inspiration algorithms. Saman et al. Almufti et al. [2019] present a taxonomy of bio-inspired algorithms focus on optimization where three classes are presented: (i) evolutionary algorithms, (ii) swarm intelligent algorithms, (iii) ecological inspired algorithms.

This proposal is made to better understanding of algorithms inspired on behavior of living beings; by this way, a taxonomy is proposed based on kingdoms and some statistics are made to establish a global tendency of this promising area.

A complete taxonomy by behaviors is included where new solutions are generated by differential vector movement and solution creation and finally a taxonomy is made considering more influential algorithms highlighting genetic algorithms, particle swarm optimization, differential evolution, ant colony optimization and artificial bee colony.

## 2 Taxonomy explanation

Specialist are established six kingdoms; however, a traditional Linnaean system of classification of living forms consider five kingdoms: (i) Monera (Bacterias, spirochetes and archaeabacteria), (ii) Protista (Algae, protozoans), (iii) Fungi (mushrooms), (iv) Plantae (plants), (v) Animalia (birds, mammals, fishes, insects, etc.). Behavior of animals has been considered in spite of a specific specie is not defined. Virus is not considered a living form; however, a class was established for them.

### 2.1 Animalia

Animalia is the biggest kingdom, made up mammals, fishes, birds, insects, and other animals (other animals are grouped because there are a reduced number of algorithms which represent them). Other algorithms inspired in behavior of animals are included, but these algorithms do no belong to any kingdom. That is the case of virus and algorithms inspired in a general behavior.

#### 2.1.1 Birds

First class of animalia belongs to birds which focus on three forms of behaviors (a) Flocking or migrating, (b) Foraging or Hunting (c) Mating or breeding. Flocking behavior is a general behavior found in birds ([Bellaachia and Bari [2012]]) and is found in several of them like emperor penguins increase heat radiation ([Harifi et al. [2019]]), migration birds ([Duman et al. [2012]]) or with a V configuration used in gooses ([Wang and Wang [2008]]), swallows ([Neshat et al. [2012]]) and in pigeons for homing behavior ([Wang et al. [2019]], [Duan and Qiao [2014]]). A more general form of flocking is made by PSO ([Kennedy and Eberhart [1995]]), and Bird Swarm ([Meng et al. [2016]])

Algorithms inspired in Foraging or searching for food are more numerous. Foraging of Hoopoe ([El-Dosuky et al. [2012]]), sparrow searching for worms, seeds and avoiding predators ([Xue and Shen [2020]]), chickens during food searching ([Meng et al. [2014]]), crows ([Askarzadeh [2016]]) and ravens searching food and sharing information about its location ([Brabazon et al. [2016]]) and egyptian vulture ([Sur et al. [2013]]) for searching food which is a similar behavior shown by american condor with its movement patterns ([Almonacid and Soto [2019]])

Several algorithms are inspired in hunting which usually is found in predator birds where eagles and Hawks are the favorites to be represented. A flock of hawks cooperatively pounce a pray from different directions ([Heidari et al. [2012]])
A 2020 Taxonomy of living beings behavior algorithms

### Table 1: Algorithms based on birds behavior.

| Swarm Algorithms                        | Acronym | Authors                                      |
|-----------------------------------------|---------|----------------------------------------------|
| Andean Condor Algorithm                 | ACA     | Almonacid and Soto [2019]                    |
| Bald Eagle Search                       | BES     | Alsattar et al. [2020]                       |
| Bird Mating Optimizer                   | BMO     | Askarzadeh [2014]                           |
| Bird Swarm                              | BrS     | Meng et al. [2016]                          |
| Chicken swarm optimization              | CKS     | Meng et al. [2014]                          |
| Crow Search Algorithm                   | CSA     | Askarzadeh [2018]                           |
| Cuckoo Optimization Algorithm           | COA     | Rajabioun [2011]                            |
| Cuckoo Search                           | CS      | Yang and Deb [2009]                         |
| Dove Swarm Optimization                 | DSO     | Su et al. [2009]                            |
| Eagle Perching Optimizer                | EPO     | Khan et al. [2018]                          |
| Eagle Strategies                        | Egs     | Yang and Deb [2010]                         |
| Egyptian Vulture Optimization           | EVO     | Sur et al. [2013]                           |
| Emperor Penguins Colony                 | EPC     | Harifi et al. [2019]                        |
| Falcon Optimization Algorithm           | FIOA    | de Vasconcelos Segundo et al. [2019]        |
| Flock by Leader                         | FbL     | Bellaachia and Barri [2012]                 |
| Goose Team Optimization                 | GTO     | Wang and Wang [2008]                        |
| Harris’ Hawk Optimization               | HrHO    | Heidari et al. [2019]                       |
| Heterogeneous Pigeon-inspired Optimization | HPIO | Wang et al. [2019]                         |
| Hoopoe Heuristic Optimization           | HHO     | El-Dosuky et al. [2012]                     |
| Laying Chicken Algorithm                | LCA     | Mellal and Williams [2016]                  |
| Migrating Birds Optimization            | MBO     | Duman et al. [2012]                         |
| Owl Search Algorithm                    | OSA     | Jain et al. [2018]                          |
| Particle Swarm Optimization             | PSO     | Kennedy and Eberhart [1995]                |
| Penguins Search Optimization Algorithm  | PnSO    | Gheraibia and Moussaoui [2013]              |
| Pigeon Inspired Optimization            | PIO     | Duan and Qiao [2014]                        |
| Raven Roosting Optimization Algorithm   | RRO     | Brabazon et al. [2016]                      |
| Satin Bowerbird Optimizer               | SBO     | Samareh Moosavi and Khatibi Bardsiri [2017] |
| SeaGull Optimization Algorithm          | SgOA    | Dhiman and Kumari [2019]                    |
| See-See Partridge Chicks Optimization   | SPCO    | Omidvar et al. [2015]                       |
| Sooty Tern Optimization Algorithm       | STOA    | Dhiman and Kaur [2019]                      |
| Sparrow Search Algorithm                | SpSA    | Xue and Shen [2020]                         |
| Swallow Swarm Optimization Algorithm    | SSOA    | Neshat et al. [2012]                        |

Strategies of hunting made by eagles (Alsattar et al. [2020], Yang and Deb [2010]) exception is made by eagles perching in higher places (mountains, cliffs, etc.) for better view for hunting (Khan et al. [2018]) and collaborative hunting of penguins (Gheraibia and Moussaoui [2013]). Mating and breeding is found in cuckoo bird which is considered a parasite where it found more promises nest to lay eggs (Yang and Deb [2009]) or mature cuckoos and eggs which try to survives in the population (Rajabioun [2011]). Other algorithm use bird mating strategies to increase opportunity of breeding (Askarzadeh [2014]); for example, laying chicken hatching eggs (Mellal and Williams [2016]) or during breeding, See-See partridge chicks follow their mother to reach a safe place (Omidvar et al. [2015]) and attraction of females by the satin birds males (Samareh Moosavi and Khatibi Bardsiri [2017]). All algorithms based on birds behavior are shown in Table 1.

#### 2.1.2 Fishes

Second class of animalia kingdom belongs to fishes. Almost all behaviors are for hunting and foraging. Catfish effect is used when a school of sardines in a water tank are motivated to move when a catfish (a natural predator) is included in the tank (Chuang et al. [2011]). Shark uses an improved version of a fish search algorithm (Li and Qian [2003]) to increase exploration procedure for hunting (Hersovici et al. [1998]). Other ability of sharks for hunting is to use smell sense (Abedinia et al. [2016]). Yellow Saddle Goaffishes forms schools for hunting taking two roles, chase to pursuit preys and blockers to avoid escapes (Zaldivar et al. [2018]).

A similar behavior is taken by sailfish for hunting sardines (Shadravan et al. [2019]). Mouth brooders fishes take care of their offsprings by using their mouth as a form of protection again environmental conditions and predators (Jahani and Chizari [2018]). The Great Salmon Run is a migration for mating where salmon return from the sea to the mountains.
Table 2: Algorithms based on fishes behavior.

| Swarm Algorithms                        | Acronym | Authors                         |
|-----------------------------------------|---------|---------------------------------|
| Catfish Optimization Algorithm          | CtOA    | Chuang et al. [2011]            |
| Circular Structure of Puffer Fish       | CSPF    | Catalbas and Gulden [2018]      |
| Fish School Search                      | FSS     | Bastos Filho et al. [2008]      |
| Fish Swarm Algorithm                    | FSA     | Li and Qian [2003]              |
| Great Salmon Run                        | GSR     | Mozaffari et al. [2012]         |
| Mouth Breeding Fish Algorithm           | MBFA    | Jahani and Chizari [2018]       |
| Shark Smell Optimization                | ShSO    | Abedinia et al. [2015]          |
| Shark-Search Algorithm                  | SSA     | Hersovici et al. [1998]         |
| The Sailfish Optimize                   | SFO     | Shadravan et al. [2019]         |
| Yellow Saddle Goat Fish                 | YSGF    | Zaldivar et al. [2018]          |

where they born overcoming all kind of menaces (Mozaffari et al. [2012]). All algorithms based on fishes behavior are shown in Table 2.

2.1.3 Insects

Third class belongs to insects where several algorithms imitate behavior of social insects; however, there are a redundancy because all insects presents the same behaviors as other animals: (i) Foraging, (ii) hunting, (iii) mating but rarely breeding, and (iv) other specific behaviors. Ants, bees and wasp presents complex social behaviors which they are very attractive to develop algorithms for emulation. Behavior of ants was first imitated to simulate the use of pheromones to establish potential sources of food or to begin a foraging process (Dorigo et al. [1996], Dorigo [1992]), with a random walk procedure to improve exploration (Yang et al. [2006], Almuti and Shaban [2018]). Other algorithms inspired in ants focus on behavior based on hunting mechanisms (Mirjalili [2015a]). Termites have exhibit the same collective behavior (Hedayatzadeh et al. [2010]) and cooperative behavior of hill building (Zungeru et al. [2012]). Bees are social insect with complex mechanism of communications and have a sort of several behaviors for foraging, mating, avoiding predators, etc. This behavior is another very attractive task to be inspired to develop swarm algorithms. Colony bees foraging made artificial is the most popular (Pham et al. [2005], Häckel and Dippold [2009], Bitam et al. [2017], Teodorovic [2009], Quijano and Passino [2010], Nakrani and Tovey [2004], Sato and Hagiwara [1997], Maa et al. [2013]) or mating process in bees where queen flights high from the nest followed by the males (Abbasi [2001]) or evolution of bees (Sung Hoon Jung [2003], Yang [2005]).

Behavior of individual insects with social interaction considers several tasks like navigation, foraging or escape from predators. This behavior have been inspired from dragonflies (Mirjalili [2016]), approaching or hovering over food sources of fruitful flies (Pan [2012], al-Rifaie [2014]), worms foraging (Arnavut [2014]), foraging and mating of butterflies (Kumar et al. [2015], Arora and Singh [2018a], Qi et al. [2017]) or only focus on males butterflies to mate-location behavior (Arora and Singh [2018b]). Long-horn beetle for searching food and avoid predators (Jiang and Li [2017]), bark beetles searching for food and a nest (Kalioras et al. [2018]), and foraging of seven spot ladybirds (Yang et al. [2013]). Attraction and flashing behaviors of fireflies (Yang [2010]) or lampyridaeis to produce light by bioluminescence for attraction of preys or mating (Oliveira et al. [2011]). Foraging and social interaction of spiders to establish the positions of preys based on detection of vibrations of the spider web (Cuevas et al. [2013], Yu and Li [2015]) or black widow spiders bizarre mating (Hayyolalam and Pourhan Kazemi [2020]). Wasps interact and allocate the tasks required in nest (Pinto et al. [2005], Meyer and Wilson [1991]). Only a collective behavior of aggregation has been represented in several algorithms, inspired on glowworms (Krishnamand and Ghose [2009]), grasshopper and locust swarm (Saremi et al. [2017], Chen [2009a]), cockroaches (Havens et al. [2008], Agarwal et al. [2014]). Migration made by monarch butterflies (Yang et al. [2015]) or mating in bumblebees (Marinakis et al. [2009]) and mayflies (Zervoudakis and Tsafarakis [2020]). Different behaviors of Mosquitos have been used considering seeking a host (Feng et al. [2015]), selection of habitat to lay eggs (ul Amir Afsar Minhas and Arif [2011]), and to find a hole in a net (Alauddin [2016]). All algorithms based on insects behavior are shown in Tables 3 and 4.

2.1.4 Mammals

Algorithms inspired in behavior of mammals are the second more numerous members of animalia kingdom since the first one are insects. A classification of behaviors is proposed again dividing algorithms for foraging, hunting and specific behaviors. Hunting behavior of some mammal predators has been represented in several algorithms, per example colony of bats using echolocation to find a prey (Yang and Gandomi [2012], Malakooti et al. [2011], Tawfeeq [2012]), canides as dogs (Subramanian et al. [2013], Ruiz-Vanoye et al. [2012], Alshorman [2014]); hyenas (Dhiman
Table 3: Algorithms based on insects behavior (part 1).

| Swarm Algorithms                        | Acronym | Authors                                      |
|-----------------------------------------|---------|----------------------------------------------|
| Ant Colony Optimization                 | ACO     | Dorigo et al. [1996], Dorigo [1992]          |
| Ant Lion                                | ALO     | S. Mirjalili [Mirjalili et al. 2015a]        |
| Artificial Bee Colony                   | ABC     | Karaboga and Basturk [2007]                  |
| Artificial Beehive Algorithm            | ABA     | Munoz Acosta et al. [2009]                   |
| Artificial Butterfly Optimization       | ABO     | Qi et al. [2017]                             |
| Bee Colony Optimization                 | BCO     | Teodorovic [2009]                            |
| Bee Colony-Inspired Algorithm           | BciA    | Hackel and Dippold [2009]                    |
| Bee Swarm Algorithm                     | BeeSA   | Meng et al. [2016]                           |
| Bee Swarm Optimization                  | BSO     | Oliveira et al. [2011]                       |
| Bee System                              | BS      | Sato and Hagiwara [1997]                     |
| Bees Algorithm                          | BA      | Pham et al. [2005]                           |
| Bees Life Algorithm                     | BLA     | Bitam et al. [2017]                          |
| Bettle Antennae Search Algorithm        | BASA    | Jiang and Li [2017]                          |
| Bioluminescent Swarm Optimization       | BSO     | Oliveira et al. [2011]                       |
| Black Widow Optimization                | BWO     | Hayyolalam and Pourhaji Kazem [2020]         |
| Bumble Bees Mating Optimization         | BBMO    | Marinakis et al. [2009]                      |
| Butterfly Optimization Algorithm        | BtOA    | Arora and Singh [2018b]                      |
| Butterfly Optimizer                     | BTO     | Kumar et al. [2015]                          |
| Coachroach Swarm Optimization           | CrSO    | Agarwal et al. [2014]                        |
| Cricket Behaviour-Based Evolutionary    | CBBE    | Canayaz and Karje [2015]                     |
| Dispersive Flies Optimization           | DFO     | al-Rifaie [2014]                             |
| Dragonfly Algorithm                     | DA      | Mirjalili [2016]                             |
| Firefly Algorithm                       | FA      | Yang [2010]                                  |
| Fruitfly Algorithm                      | FiA     | Pan [2012]                                   |

Aggregation of mammals for foraging, searching or feeding behavior is very common in rumiantes like buffalo (Man et al. 2016), bison (Kazikova et al. 2019), camel (Ali 2016), and the elephants (Wang et al. 2015), Deb et al. 2015), the squirrels (Jain et al. 2019), flying squirrel (Miarnaeimi et al. 2019) and searching behavior of the donkeys to find routes (Shamsaldin et al. 2019).

An artificial selection of the best individual, a form of extreme elitism is made in bull to be selected to generate strong and better offsprings (FINDIK 2015). A similar mechanism of competition for mating is made by Reed Deer (Fathollahi-Fard et al. 2020) or lions prides behavior (Wang et al. 2012) where strongest males have high probabilities for mating and eliminate other competitors inclusive theirs offsprings.

Marine mammals have serve as inspiration to several algorithms specially dolphins and whales. The use of echolocation (Kaveh and Farhoudi 2013) or hunting strategies where information is shared between dolphins is commonly used as inspiration (Zhao et al. 2015, Shiqlin et al. 2009, Serani and Diez 2017). The same behavior is used in gray whales for foraging strategies using burbles (Mirjalili and Lewis 2016) or searching and hunting like sperm whale (Ebrahim and Khamenechi 2016) or killer whale (Biyanto et al. 2017).

A more complex behavior can be observed in several primates like spider monkey (Bansal et al. 2014), blue monkeys (Mahmood and Al-Kateeb 2019), ageist monkeys which age could bring a difference for better performance to solve problems (Sharma et al. 2016) and sexual behavior with individual intelligence of chimps (Khishe and Mosavi 2020). Humans are considered primates and have the same behavior but in a more sophisticated way to form tribes (Chen et al. 2010), groups (Thammano and Moowong 2010, Zhang et al. 2009) or aggregates as crowds (R. Yampolskiy and Hassan 2012) (More complex behaviors unique for humans are not considered here because it is very difficult to be expressed by other species) All algorithms based on mammals behavior are shown in Tables 5 and 6.
Table 4: Algorithms based on insects behavior (part 2).

| Swarm Algorithms                                      | Acronym | Authors                                      |
|-------------------------------------------------------|---------|----------------------------------------------|
| Glowworm Swarm Optimization Algorithm                 | GSO     | Krishnanand and Ghose [2009]                 |
| Grasshopper Optimisation Algorithm                    | GOA     | Saremi et al. [2017]                         |
| Group Mosquito host-seeking algorithm                 | GMHA    | Feng et al. [2015]                           |
| Honey Bee Behavior                                    | HBB     | Wedde et al. [2004]                          |
| Honey Bees Optimization                              | HBO     | Nakram and Tovey [2004]                      |
| Honey-bees Mating Optimization Algorithm              | HBMOA   | Abbass [2001]                                |
| Honeybee Social Foraging                             | HSF     | Quijano and Passino [2010]                   |
| Locust Swarm                                         | LS      | Stephen Chen Chen [2009a]                     |
| Mayfly Optimization Algorithm                        | MayfOA  | Zervoudakis and Tsalakakis [2020]             |
| Monarch Butterfly Optimization                       | MnBO    | Wang et al. [2015]                           |
| Mosquito Fly Optimization                            | MqFO    | Ataaddini [2016]                             |
| Mosquitos Oviposition                                | MOX     | Feng et al. [2015]                           |
| Moth-flame Optimization Algorithm                    | MOA     | Mirjalili [2013b]                            |
| Mox Optimization Algorithm                           | MOA     | ul Amir Afsar Minhas Arif [2011]             |
| OptBees                                               | OB      | Maia et al. [2013]                           |
| Pity Beetle Algorithm                                | PBA     | Kallioras et al. [2018]                      |
| Queen-bees Evolution                                 | QBE     | Sung Hoon Jung [2003]                        |
| Regular Butterfly Optimization Algorithm              | RBOA    | Arora and Singh [2018a]                      |
| Roach Infestation Optimization                      | RIO     | Havens et al. [2008]                         |
| Seven-spot Ladybird Optimization                     | SLO     | Yang et al. [2013]                           |
| Social Spider Algorithm                               | ScSA    | Cuevas et al. [2013]                         |
| Social Spider Optimization                           | SSO     | Yu and Li [2015]                             |
| Termite Colony Optimization                          | TCO     | Hedayatzadeh et al. [2010]                   |
| Termite Hill Algorithm                                | THA     | Zungeru et al. [2012]                        |
| U-Turning Ant Colony Optimization                     | U-TACO  | Almutti and Shaban [2018]                     |
| Virtual Ants Algorithm                                | VAA     | Yang et al. [2006]                           |
| Virtual Bees Algorithm                                | VBA     | Yang [2005]                                  |
| Wasp Colonies Algorithm                              | WCA     | Meyer and Wilson [1991]                      |
| Wasp Swarm Optimization                              | WSO     | Pinto et al. [2005]                          |
| Worm Optimization                                    | WO      | Arnaout [2014]                               |

2.1.5 Others living beings from animalia

Fifth class is a group of several classes of algorithms which are inspired in behavior of other animals or phylum with a low number of representations. These groups of animals like mollusks where cuttlefish is a cepholopod which establish a correct color to mimic on the environment (Eesa et al. [2013]), krill living for foraging and reproduction (Gandomi and Alavi [2012]), bed formations by leisurely locomotion of mussels for survival (An et al. [2013]) or swarm behavior of salps to navigate and forage (Mirjalili et al. [2017]).

Different corals fighting with other coral for space on the reef (Tsai et al. [2014]) and Zooplankton which integrates several species of animals, larve, and other organisms (Ruiz-Vanoye et al. [2012]). Amphibius have been considered like behavior of japanese tree frogs where for mating, males frogs calls females through desynchronization calls (Mutazono et al. [2009]). Others frogs interchange elements of cultural information called memes; some of them are hosts an others are carriers. This behavior is used to improve exploration and exploitation for foraging (Eusuff et al. [2006]). Mating by polymorphic of side-blotched lizards (Maciel C. et al. [2020]) or simply foraging of frogs (Garcia and Moreno-Pérez [2008]). Finally, algorithms for optimization based on animal behavior are inspired in a general performance of animals without a given specification of the species or it can be applied to any species. This could be assumed to humans only but; in some cases, it could be presented in another animals like ants, bees, wolfs, or whales. Complex behavior like simbiosis (Cheng and Prayogo [2014]), formation of structures (Su et al. [2007]) or a high order of behavior like cooperation (Civicioglu [2013]) and competition (Mohseni et al. [2014]) is used. However, other algorithms emphasize collective behaviors trying to form a general swarm algorithm like Universal Swarm Optimizer (Marázquez-Vega and Torres-Treviño [2013]), hierarchy formation (Reggiani et al. [2010]) or to pursuit an objective, like search (He et al. [2006]) aggregation (Chen [2009b], Piccardi et al. [2012], Cui et al. [2006]), hunting a prey (Oftadeh and Mahjoob [2009], Tilahun et al. [2015]) or migration (Li et al. [2014], Chen and Wang [2009], Li [2004]). All algorithms based on a general animal based behavior are shown in Table 7.
Table 5: Algorithms based on mammals behavior (part 1).

| Swarm Algorithms                                      | Acronym | Authors                                |
|-------------------------------------------------------|---------|----------------------------------------|
| African Buffalo Optimization                          | ABO     | Man et al. [2016]                      |
| African Wild Dog Algorithm                            | AWDA    | Subramanian et al. [2013]              |
| Ageist Spider Monkey Optimization                    | ASMO    | Sharma et al. [2016]                   |
| Artificial Tribe Algorithm                            | ATA     | Chen et al. [2010]                     |
| Bat Algorithm                                         | BA      | Yang and Gandomi [2012]                |
| Bat Intelligence                                      | BI      | Maitakoun et al. [2011]                |
| Bat Sonar Algorithm                                   | BSA     | Jawleeq [2012]                         |
| Bison Behavior Algorithm                              | BBA     | Kazikova et al. [2019]                 |
| Blind, Naked Mole-rats Algorithm                      | BNMR    | Taherdangko et al. [2013]              |
| Bull Optimization Algorithm                          | BllOA   | FINDIK [2015]                          |
| Camel Algorithm                                       | CA      | Ali [2016]                             |
| Cat Swarm Optimization                                | CSO     | Chu et al. [2006]                      |
| Cheetah Chase Algorithm                               | CCA     | Groudhamian [2018]                     |
| Chimp Optimization Algorithm                         | COA     | Khishe and Mosavi [2020]               |
| Coyote Optimization Algorithm                         | CyOA    | Pierezanz and Dos Santos Coelho [2018] |
| Cultural Coyote Optimization Algorithm                | CCOA    | Pierezanz et al. [2019]                |
| Dolphin Echolocation                                 | DphE    | Kaveh and Farhoudi [2013]              |
| Dolphin Herd Algorithm                                | DHA     | Zhao et al. [2015]                     |
| Dolphin Partner Optimization                          | DPO     | Shiqin et al. [2009]                   |
| Dolphin Pod Optimization                              | DpdO    | Serani and Diez [2017]                 |
| Donkey and Smuggler Optimization Algorithm            | DsOA    | Shamsaldin et al. [2019]               |
| Elephant Herding Optimization                         | EHO     | Wang et al. [2015]                     |
| Elephant Search Algorithm                             | ESA     | Deb et al. [2015]                      |
| Feral, Dogs Herd algorithm                            | FDHA    | Ruiz-Vanoey et al. [2012]              |
| Flying Squirrel Optimizer                             | FSO     | Miarneami et al. [2019]                |
| Gray Wolf Optimizer                                   | GWO     | Mirjahi et al. [2014]                  |
| Human Group Formation                                 | HGF     | Thammamano and Moofwong [2010]         |
| Human-inspired Algorithm                              | HIA     | Zhang et al. [2009]                    |
| Jaguar Algorithm with Learning Behavior               | JA      | Chen et al. [2015]                     |

2.2 Bacteria

In this subsection are combined two kingdoms to consider bacteria and archaebacteria. Bacteria have several complex behaviors for survival; all algorithms are inspired a life cycling of bacterias, from foraging, reproduction, elimination (Chen et al. [2007], Zhang et al. [2012], Das et al. [2009], Passino [2002], Ying Chu et al. [2008], Anandaraman et al. [2012]) communication by chemotaxis (Muller et al. [2002]). Some bacterias orient and swim through geomagnetic fields or by magnetostatic for foraging (Mo and Xu [2013]). All algorithms based on bacterial behavior are shown in Table 8.

2.3 Fungi

There is only one algorithm that belong to this kingdom which it is inspired in mushrooms, specifically in their reproduction and growth mechanisms made in nature. Mushrooms expulse spores to discover good living conditions for growing and develop colonies (Bidar et al. [2018]).

2.4 Plants

Growing of plants as an adaptive phenomenon is represented in several algorithms like transmission mode of bean seeds (Xiaoming Zhang et al. [2010]). The growing process of trees where branches growth toward betters positions by phototropism and photosynthesis (Li et al. [2012]). In a more sophisticated way, a complete process of a forest growth has been represented where trees can live more time in specific zones and others trees can not (Ghaemi and Fetic-Derakhshi [2014]). Some Seeds falls near of these trees but others are taken to another promising zones. A similar process where an artificial plant growth is represented including growth of leaves and spatial branching by phototropism (Cai et al. [2008]). Strawberry plant which try to find better conditions of water, light and nutrients investing more in promising near neighbor spots has inspired some algorithms (Merrikh-Bayat [2014]). The colonization in a cropping of invasive weeds (Mehrabian and Lucas [2006]). Seeds in more fertile soils, grow more and produce more seeds on paddy
Table 6: Algorithms based on mammals behavior (part 2).

| Swarm Algorithms                  | Acronym | Authors                        |
|-----------------------------------|---------|--------------------------------|
| Killer whale algorithm            | KWA     | Biyanto et al. [2017]          |
| Leader of Dolphin Herd Algorithm  | LDHA    | Zhao et al. [2015]             |
| Lion Optimization Algorithm       | LOA     | Yazdani and Jolai [2015]       |
| Lion Pride Optimizer              | LPO     | Wang et al. [2012]             |
| Meerkats Clan Algorithms          | MCA     | Al-Obandi et al. [2018]        |
| Meerkats Inspired Algorithm       | MIA     | Klein and dos Santos Coelho [2018] |
| Monkey Search                     | MS      | Mucherino and Serel [2007]     |
| Naked Moled Rat                   | NMR     | Salgolra and Singh [2019]      |
| Polar Bear Optimization Algorithm | PBOA    | Polap and Wozniak [2017]       |
| Raccoon Optimization Algorithm    | ROA     | Zangbari Koohi et al. [2019]   |
| Rats Herd Algorithm               | RATHA   | Ruz-Vanoye et al. [2012]       |
| Red Deer Algorithm                | RDA     | Fathollahi-Fard et al. [2020]  |
| Rhino Herd Behavior               | RHB     | Wang et al. [2018]             |
| Sea Lion Optimization Algorithm   | SLnOA   | Wang et al. [2012]             |
| Sheep Flocks Heredity Model       | SFHM    | Nara et al. [1999]             |
| Sperm Whale Algorithm             | SWA     | Ebrahimi and Khamelchi [2016]  |
| Spider Monkey Optimization        | SMO     | Bansat et al. [2014]           |
| Spotted Hyena Optimizer           | SHO     | Dhiman and Kumar [2017]        |
| Squirrel Search Algorithm         | SqSA    | Jain et al. [2019]             |
| The Blue Monkey                   | TBM     | Mannood and Al-Khateeb [2019]  |
| Whale Optimization Algorithm      | WOA     | Mirjalili and Lewis [2016]     |
| Wild Dog Packs                    | WDP     | Alshorman [2014]               |
| Wildebeests Herd Optimization     | WHO     | Motevali et al. [2019]         |
| Wisdom of Artificial Crowds       | WAC     | R. Yampolskiy and Hassan [2012]|
| Wolf Colony Algorithm             | WICA    | Liu et al. [2011]              |
| Wolf Pack Search                  | WPSA    | Yang et al. [2007]             |
| Wolf Search Algorithm             | WSA     | Tang et al. [2012]             |

Table 7: Algorithms based on animal behavior.

| Swarm Algorithms                  | Acronym | Authors                        |
|-----------------------------------|---------|--------------------------------|
| Animal Migration Optimization Algorithm | AMO | Li et al. [2014]               |
| Artificial Cooperative Search Algorithm | ACSA | Civicioglu [2013]             |
| Artificial Searching Swarm Algorithm | ASSA | Chen [2009]                    |
| Collective Animal Behavior        | CAB     | Piccardi et al. [2012]        |
| Competition Over Resources        | COR     | Mohseni et al. [2014]         |
| Flocking-based Algorithm          | FBA     | Cui et al. [2006]              |
| Good Lattice Swarm Optimization   | GLSO    | Su et al. [2007]               |
| Group Search Optimizer            | GpSO    | He et al. [2006]               |
| Hierarchical Swarm Model          | HSM     | Reggiani et al. [2010]         |
| Hunting Search Optimization       | HSO     | Oftadeh and Mahjoob [2009]     |
| Population Migration Algorithm    | PMA     | Chen and Wang [2009]           |
| Predator Prey Algorithm           | PdPA    | Tilahun et al. [2015]          |
| Self-Organized Migration Algorithm | SOM | Cheng and Prayogo [2014]       |
| Universal Swarm Optimizer         | USO     | Márquez-Vega and Torres-Treviño [2018] |

fields (Premaratne et al. [2009]). Other mechanisms used by plants to defend against different predators since fungus, to insects or herbivores (Caraveo et al. [2018]). Pollination process of the flowers represents different strategies followed by the plants to increase its reproduction (Ghaemi and Feizi-Derakhshi [2014]), and the growth of roots to search high nutrients (Herreros et al. [2015], Labbi et al. [2016]). A representation of the growth of root tree for searching wet soil (Merrikh-Bayat [2015]). All algorithms based on plants mechanisms are shown in Table 9.

2.5 Protista

Living forms that belong to Protista kingdom has inspired some algorithms, i.e. Adaptation and movement of microalgae (Uymaz et al. [2015]). Slime mould movement as propagation wave through paths for food by bio-oscillatory
A 2020 Taxonomy of living beings behavior algorithms

Table 8: Algorithms based on bacterial behavior.

| Swarm Algorithms                          | Acronym  | Authors                        |
|-------------------------------------------|----------|--------------------------------|
| Bacterial GA Foraging                     | BGAF     | Chen et al. [2007]             |
| Bacterial Chemotaxis Algorithm            | BCA      | Muller et al. [2002]           |
| Bacterial Colony Optimization             | BeCO     | Zhang et al. [2012]            |
| Bacterial Evolutionary Algorithm          | BEA      | Das et al. [2009]              |
| Bacterial Foraging Algorithm              | BFA      | K.M. Passino [2002]           |
| Bacterial Swarming                        | BS       | Ying Chu et al. [2008]         |
| Magnetotactic Bacteria Optimization Algorithm | MBOA   | Mo and Xu [2013]               |
| SuperBug Algorithms                       | SBA      | Anandaraman et al. [2012]      |

Table 9: Algorithms based on plants behavior.

| Swarm Algorithms                          | Acronym  | Authors                        |
|-------------------------------------------|----------|--------------------------------|
| Artificial Plant Optimization Algorithm   | APOA     | Li et al. [2012]               |
| Bean Optimization Algorithm               | BOA      | Xiaoming Zhang et al. [2010]   |
| Flower Pollination Algorithm              | FPA      | Yang [2012]                    |
| Forest Optimization Algorithm             | FOA      | Ghaemi and Feizi-Derakhshi [2014] |
| Invasive Weed Optimization                | IWO      | Mehrabian and Lucas [2006]     |
| Natural Forest Regeneration               | NFR      | Moez et al. [2010]             |
| Paddy Field algorithm                     | PFA      | Premaratne et al. [2009]       |
| Plant Growth Optimization                 | PGO      | Cai et al. [2008]              |
| Plant Propagation Algorithm               | PPA      | Salih and Fraja [2011]         |
| Root Growth Optimizer                     | RGO      | Herrera et al. [2015]          |
| Rooted Tree Optimization Algorithm        | RTOA     | Labri et al. [2016]            |
| Runner-Root Algorithm                     | RRA      | Merrirh-Bayatt [2015]          |
| Sapling Growing up Algorithm              | SGUA     | Karci and Alatas [2006]        |
| Seed Based Plant Propagation Algorithm    | SBPPA    | Li et al. [2015]               |
| Self-defense Techniques of the Plants     | SDTP     | Caraveo et al. [2018]          |
| Strawberry Algorithm                      | SA       | Merrirh-Bayatt [2014]          |

movement has inspired some algorithms [Monismith and Mayfield [2008]). A similar behavior is made by Amoeboid Organisms [Xiaoge Zhang et al. [2012]).

2.6 Viruses

Finally, virus do not belong to any kingdom; however, they represent their own kingdom according with some authors; however they have an iteration with species of other kingdoms. The capabilities to infect successfully cells and produce new viruses is represented in [Cortés et al. [2008], Li et al. [2016], Liang and Juarez [2016], Jaderyan and Khotanlou [2016]). A more recent algorithm inspired in viruses behavior is Coronavirus optimization algorithm which is based on propagation of COVID-19 illness [Martínez-Alvarez et al. [2020]].

2.7 Who is who in living being inspired algorithms

Complete taxonomy is shown in Figure 1. Observing trajectory of development of swarm algorithms inspired in living being behaviors, there is a tendency where the number of new proposal is increasing (Figure 2).

An analysis was made considering references of this review to count algorithms proposed by authors and journals with more publications related with living beings behavior based inspired algorithms. Authors with more than two algorithms were considered inclusive mentioned as coauthors in original papers. Xin-She Yang (Author or involved in Cuckoo Search, Firefly Algorithm, Bat Algorithm, Flower Pollination Algorithm, Eagle Strategies, Virtual Ants and Bees, Catfish optimization algorithm) and Seyedali Mirjalili (Grey Wolf Algorithm, Whale Optimization Algorithm, Salp Swarm Algorithm, Ant Lion Optimization, Grasshopper Optimization Algorithm, Moth Flame Optimization Algorithm, Harris Hack Optimization) are the most prominent authors. Special mentions for Erik Cuevas (Side-Blotched Lizard Algorithm, Locust Swarm algorithm, Social Spider Algorithm, Yellow Saddle Goatfish), Jorge A. Ruíz -Vanoye (Rats Herd Algorithm, Feral Dogs Herd Algorithm, Dolphin Herd Algorithm, Zooplakton Swarm Algorithm), Kevin M. Passino (biomimicry of bacterial foraging, Honeybee social foraging algorithm), and Vijay Kumar (Seagull Optimization Algorithm, Spotted Hyena Optimization). Journal with more than four related publications are Applied Soft Computing,
3 Conclusion

A new taxonomy is presented based on kingdom classifications and considering all known nature inspired living being algorithms. Several algorithms have been proposed in recent years, it makes a feeling that many of them do not contribute to discipline or there is an abuse to promote new algorithms. Inclusive some authors propose the use of only well established algorithms; by this way, they consider that it is not necessary to generate new algorithms only use better ones. Perhaps many algorithms could be useless, poorly tested or applied. Many of them have not tested intensively in different well known benchmarks; nevertheless, my particular opinion is that the doors should not close to new algorithms because they may contribute to new ideas, i.e. new behaviors for swarm robotics and perhaps appears a new revolutionary algorithm.

Finally, some authors are proposed an unifications of algorithms to establish universal algorithms, it is not clear because Not Free Lunch Theory make not possible this condition but it has not been proven. In part because a mathematical foundation is required; however, in evolutionary or meta heuristics algorithms this problem persists until now. As a future work, highlighted algorithms based on behaviors of living forms could be included and make a study which includes memory used, computational complexity and parameters required. For this analysis a seudo-code of every
algorithms must be generated in a homogenous way to allow comparisons between them. This is a monumental work, however, we can reduce this work considering most highlighted algorithms of every kingdom.

Figure 2: Quantity of new proposals for year.
References

Parul Agarwal and Shikha Mehta. Nature-inspired algorithms: State-of-art, problems and prospects. *International Journal of Computer Applications*, 100:14–21, 08 2014. doi:10.5120/17593-8331

Nazmul H. Siddique and Hojjat Adeli. Nature inspired computing: An overview and some future directions. *Cognitive Computation*, 7:706 – 714, 2015.

P. Sindhuj, P. Ramamoothy, and M. Suresh Kumar. A brief survey on nature inspired algorithms: Clever algorithms for optimization. *Asian Journal of Computer Science and Technology (AJCST)*, 7(1):27–32, 2018.

Avula Krishnaveni. A survey on natural inspired computing (nic): Algorithms and challenges. *Global journal of computer science and technology*, 2019.

Erik Cuevas, Fernando Fausto, and Adrián González. An introduction to nature-inspired metaheuristics and swarm methods. In *New Advancements in Swarm Algorithms: Operators and Applications*, pages 1–41. Springer, 2020.

Xin-She Yang. Nature-inspired optimization algorithms: Challenges and open problems. *Journal of Computational Science*, page 101104, 2020. ISSN 1877-7503. doi:https://doi.org/10.1016/j.jocs.2020.101104. URL http://www.sciencedirect.com/science/article/pii/S1877750320300144

V. Sureka, L. Sudha, G. Kavya, and K. B. Aruna. Nature inspired meta-heuristic optimization algorithms capitalized. In *6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, pages 1029–1034, 2020.

Julius Beneoluchi Odili, Ahmad Noraziah, Radzi Ambar, and Mohd Helmy Abd Wahab. A critical review of major nature-inspired optimization algorithms. In *The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), ICRES 2018: International Conference on Research in Education and Science*, volume 2, pages 376–394, 2018.

S Binita and S. Siva Sathya. A survey of bio inspired optimization algorithms. *International Journal of Soft Computing and Engineering (IJSCE)*, 2(2), 2012.

N. Pazhaniraja, P. V. Paul, G. Roja, K. Shanmugapriya, and B. Sonali. A study on recent bio-inspired optimization algorithms. In *2017 Fourth International Conference on Signal Processing, Communication and Networking (ICSCN)*, pages 1–6, 2017.

Rowida Ali AL. Amry and Ghaleb Al-Gaphari. Survey on recent bio-inspired optimization algorithms. *International Journal of Computer Science and Network*, 7(6), 2018.

Javier Del Ser, Eneko Osaba, Daniel Molina, Xin-She Yang, Sancho Salcedo-Sanz, David Camacho, Swagatam Das, Ponnuthurai N. Suganthan, Carlos A. Coello Coello, and Francisco Herrera. Bio-inspired computation: Where we stand and what’s next. *Swarm and Evolutionary Computation*, 48:220 – 250, 2019. ISSN 2210-6502. doi:https://doi.org/10.1016/j.swevo.2019.04.008. URL http://www.sciencedirect.com/science/article/pii/S2210650218310277

R.S. Parpinelli and H.S. Lopes. New inspirations in swarm intelligence: A survey. *International Journal of Bio-Inspired Computation (IBIC)*, 3(1):1–16, 2011.

Jorge Ruiz-Vanoye, Ocotlán Díaz-Parra, Felipe Cocón, Andres Soto, Ma Arías, Gustavo Verdúzco, and Roberto Alberto-Lira. Meta-heuristics algorithms based on the grouping of animals by social behavior for the traveling salesman problem. *International Journal of Combinatorial Optimization Problems and Informatics*, 3:104–123, 07 2012.

Bo Xing and Wen-Jing Gao. *Innovative Computational Intelligence: A Rough Guide to 134 Clever Algorithms*. Springer, 2019.

Saman M. Almufti. Historical survey on metaheuristics algorithms. *International Journal of Scientific World*, 7(1):1–12, 2019. ISSN 2307-9037. doi:10.14419/ijsw.v7i1.29497. URL https://www.sciencemag.org/doi/10.14419/ijsw.v7i1.29497

Haiping Ma, Shigen Shen, Mei Yu, Zhile Yang, Minrui Fei, and Huiyu Zhou. Multi-population techniques in nature inspired optimization algorithms: A comprehensive survey. *Swarm and Evolutionary Computation*, 44:365–387, FEB 2019. ISSN 2210-6502. doi:10.1016/j.swevo.2018.04.011

Michalis Mavrovouniotis, Changhe Li, and Shengxiang Yang. A survey of swarm intelligence for dynamic optimization: Algorithms and applications. *Swarm and Evolutionary Computation*, 33:1 – 17, 2017. ISSN 2210-6502. doi:https://doi.org/10.1016/j.swevo.2016.12.005. URL http://www.sciencedirect.com/science/article/pii/S2210650216302541
Ankit Thakkar and Kinjal Chaudhari. A comprehensive survey on portfolio optimization, stock price and trend prediction using particle swarm optimization. *ARCHIVES OF COMPUTATIONAL METHODS IN ENGINEERING*, 2020. ISSN 1134-3060. doi:10.1007/s11831-020-09448-8

Bach Hoai Nguyen, Bing Xue, and Mengjie Zhang. A survey on swarm intelligence approaches to feature selection in data mining. *SWARM AND EVOLUTIONARY COMPUTATION*, 54, MAY 2020. ISSN 2210-6502. doi:10.1016/j.swevo.2020.100663

Weifeng Sun, Min Tang, Lijun Zhang, Zhiqiang Huo, and Lei Shu. A Survey of Using Swarm Intelligence Algorithms in IoT. *SENSORS*, 20(5), MAR 2020. doi:10.3390/s20051420

Ashraf Darwish, Aboul Ella Hassanien, and Swagatam Das. A survey of swarm and evolutionary computing approaches for deep learning. *ARTIFICIAL INTELLIGENCE REVIEW*, 53(3):1767–1812, MAR 2020. ISSN 0269-2821. doi:10.1007/s10462-019-09719-2

Absalom E. Ezugwu. Nature-inspired metaheuristic techniques for automatic clustering: a survey and performance study. *SN APPLIED SCIENCES*, 2(2), FEB 2020. ISSN 2523-3963. doi:10.1007/s42452-020-2073-0

Xiaohua Chen, Genggeng Liu, Naixue Xiong, Yaru Su, and Guolong Chen. A Survey of Swarm Intelligence Techniques in VLSI Routing Problems. *IEEE ACCESS*, 8:26266–26292, 2020. ISSN 2169-3536. doi:10.1109/ACCESS.2020.2971574

Krishna Gopal Dhal, Swarnajit Ray, Arunita Das, and Sanjoy Das. A Survey on Nature-Inspired Optimization Algorithms and Their Application in Image Enhancement Domain. *ARCHIVES OF COMPUTATIONAL METHODS IN ENGINEERING*, 26(5):1607–1638, NOV 2019. ISSN 1134-3060. doi:10.1007/s11831-018-9289-9

Petr Bujok, Josef Tvrdík, and Radka Poláková. Comparison of nature-inspired population-based algorithms on continuous optimisation problems. *Swarm and Evolutionary Computation*, 50:100490, 2019. ISSN 2210-6502. doi:https://doi.org/10.1016/j.swevo.2019.01.006. URL https://www.sciencedirect.com/science/article/pii/S2210650218301536

Haiping Ma, Sengang Ye, Dan Simon, and Minrui Fei. Conceptual and numerical comparisons of swarm intelligence optimization algorithms. *Soft Computing*, 21(11):3081–3100, 2017. doi:10.1007/s00500-015-1993-x. URL https://doi.org/10.1007/s00500-015-1993-x

Alexandros Tzanetos and Georgios Dounias. An application-based taxonomy of nature inspired intelligent algorithms. technical report. Technical report, University of the Aegean, november 2019.

Ku Ruhana. Yasear, Shaymah Akram; Ku-Mahamud. Taxonomy of memory usage in swarm intelligence-based metaheuristics. *BAGHDAD SCIENCE JOURNAL*, Special Issue, 16(2):445–452, March 2019. doi:10.21123/bsj.2019.16.2(SI).0445

Daniel Molina, Javier Poyatos, Javier Del Ser, Salvador García, Amir Hussain, and Francisco Herrera. Comprehensive taxonomies of nature- and bio-inspired optimization: Inspiration versus algorithmic behavior, critical analysis recommendations. *Cognitive Computation*, 2020. doi:10.1007/s12559-020-09730-8. URL https://doi.org/10.1007/s12559-020-09730-8

Saman M. Almufti, Ridwan Boya Maqras, and Vaman Ashqi Saeed. Taxonomy of bio-inspired optimization algorithms. *Journal of Advanced Computer Science & Technology*, 8(2):23–31, March 2019. doi:10.14419/jacst.v8i2.29402. URL https://www.sciencepubco.com/index.php/JACST/article/view/29402

Abdelghani Bellaachia and Anasse Bari. Flock by leader: A novel machine learning biologically inspired clustering algorithm. In *Advances in Swarm Intelligence*. ICSI 2012. *Lecture Notes in Computer Science*, volume 7332, pages 117–126, 06 2012. doi:10.1007/978-3-642-31020-1_15

Sasan Harifi, Madjid Khalilian, Javad Mohammadzadeh, and Sadoullah Ebrahimnejad. Emperor penguins colony: a new metaheuristic algorithm for optimization. *Evolutionary Intelligence*, 12(2):211–226, 2019.

Ekrem Duman, Mitat Uysal, and Ali Fuat Akkaya. Migrating birds optimization: A new metaheuristic approach and its performance on quadratic assignment problem. *Information Sciences*, 217:65 – 77, 2012. ISSN 0020-0255.
X. Yang and Suash Deb. Cuckoo search via lévy flights. In 2009 World Congress on Nature Biologically Inspired Computing (NaBIC), pages 210–214, Dec 2009. doi:10.1109/NABIC.2009.5393690

Ramin Rajabioun. Cuckoo optimization algorithm. Applied Soft Computing, 11(8):5508 – 5518, 2011. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2011.05.008 URL http://www.sciencedirect.com/science/article/pii/S1568494611001670

Ali Reza Askarzadeh. Bird mating optimizer: An optimization algorithm inspired by bird mating strategies. Communications in Nonlinear Science and Numerical Simulation, 19(4):1213 – 1228, 2014. ISSN 1007-5704. doi:https://doi.org/10.1016/j.cnsns.2013.08.027 URL http://www.sciencedirect.com/science/article/pii/S1007570413003778

Mohamed Arezki Mellal and Edward J. Williams. Parameter optimization of advanced machining processes using cuckoo optimization algorithm and hoopoe heuristic. Journal of Intelligent Manufacturing, 27(5):927–942, 2016.

R. Omidvar, H. Parvin, and F. Rad. Sspco optimization algorithm (see-see partridge chicks optimization). In 2015 Fourteenth Mexican International Conference on Artificial Intelligence (MICAI), pages 101–106, 2015. doi:10.1109/MICAI.2015.22.

Seyyed Hamid Samareh Moosavi and Vahid Khatibi Bardsiri. Satin bowerbird optimizer: A new optimization algorithm to optimize anfis for software development effort estimation. Engineering Applications of Artificial Intelligence, 60:1 – 15, 2017. ISSN 0952-1976. doi:https://doi.org/10.1016/j.engappai.2017.01.006 URL http://www.sciencedirect.com/science/article/pii/S0952197617300064

Gaurav Dhiman and Amandeep Kaur. Stoa: A bio-inspired based optimization algorithm for industrial engineering problems. Engineering Applications of Artificial Intelligence, 82:148 – 174, 2019.

Oveis Abedinia, Nima Amjadi, and Ali Ghasemi. A new metaheuristic algorithm based on shark smell optimization. Complexity, 21(5):97–116, 2016. doi:10.1002/cplx.21634 URL https://onlinelibrary.wiley.com/doi/abs/10.1002/cplx.21634

Daniel Zaldívar, Bernardo Morales, Alma Rodríguez, Arturo Valdivia-G, Erik Cuevas, and Marco Pérez-Cisneros. A novel bio-inspired optimization model based on yellow saddle goatfish behavior. Biosystems, 174:1 – 21, 2018. ISSN 0303-2647. doi:https://doi.org/10.1016/j.biosystems.2018.09.007

Oveis Abedinia, Nima Amjadi, and Ali Ghasemi. A new metaheuristic algorithm based on shark smell optimization. Complexity, 21(5):97–116, 2016. doi:10.1002/cplx.21634 URL https://onlinelibrary.wiley.com/doi/abs/10.1002/cplx.21634

Michael Hersovici, Michal Jacovi, Yoelle S. Maarek, Dan Pelleg, Menachem Shtalhaim, and Sigalit Ur. The shark-search algorithm: an application: tailored web site mapping. Computer Networks and ISDN Systems, 30(1):317 – 326, 1998. ISSN 0169-7552. doi:https://doi.org/10.1016/S0169-7552(98)00038-5 URL http://www.sciencedirect.com/science/article/pii/S0169755298000385

H. Parvin, F. Rad, and R. Omidvar. Sspco optimization algorithm (see-see partridge chicks optimization). In Proceedings of the Seventh International World Wide Web Conference.

Oveis Abedinia, Nima Amjadi, and Ali Ghasemi. A new metaheuristic algorithm based on shark smell optimization. Complexity, 21(5):97–116, 2016. doi:10.1002/cplx.21634 URL https://onlinelibrary.wiley.com/doi/abs/10.1002/cplx.21634

Ehsan Jahani and Mohammad Chizari. Tackling global optimization problems with a novel algorithm – mouth brooding fish algorithm. Applied Soft Computing, 62:987 – 1002, 2018. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2017.09.035 URL http://www.sciencedirect.com/science/article/pii/S1568494617305744
Ahmad Mozaffari, Alireza Fathi, and Saeed Behzadipour. The great salmon run: a novel bio-inspired algorithm for artificial system design and optimisation. *International Journal of Bio-Inspired Computation (IJIBIC)*, 4(5), 2012. doi:https://doi.org/10.1504/IJBIC.2012.049889

M. C. Catalbas and A. Gulten. Circular structures of puffer fish: A new metaheuristic optimization algorithm. In *2018 Third International Conference on Electrical and Biomedical Engineering, Clean Energy and Green Computing (EBECEGC)*, pages 1–5, 2018.

C. J. A. Bastos Filho, F. B. de Lima Neto, A. J. C. C. Lins, A. I. S. Nascimento, and M. P. Lima. A novel search algorithm based on fish school behavior. In *2008 IEEE International Conference on Systems, Man and Cybernetics*, pages 2646–2651, 2008. doi:10.1109/ICSMC.2008.4811695

M. Dorigo, V. Maniezzo, and A. Colorni. Ant system: optimization by a colony of cooperating agents. *IEEE Transactions on Systems, Man, and Cybernetics, Part B (Cybernetics)*, 26(1):29–41, Feb 1996. ISSN 1083-4419. doi:10.1109/3477.484436

Marco Dorigo. *Optimization, Learning and Natural Algorithms*. PhD thesis, Politecnico di Milano, Milano, Italia, 1992.

Xin-She Yang, Janet M. Lees, and Chris T. Morley. Application of virtual ant algorithms in the optimization of cfpr shear strengthened precracked structures. In Vassil N. Alexandrov, Geert Dick van Albada, Peter M. A. Sloot, and Jack Dongarra, editors, *Computational Science – ICCS 2006*, pages 834–837, Berlin, Heidelberg, 2006. Springer Berlin Heidelberg. ISBN 978-3-540-34380-6.

Saman Almufti and Awaz Shaban. U-turning ant colony algorithm for solving symmetric traveling salesman problem. *Academic Journal of Nawroz University*, 7(4):45–49, 2018. ISSN 2520-789X. doi:10.25007/ajnu.v7n4a270. URL http://journals.nawroz.edu.krd/index.php/ajnu/article/view/270.

Seyedali Mirjalili. The ant lion optimizer. *Advances in Engineering Software*, 83:80 – 98, 2015a. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2015.01.010. URL http://www.sciencedirect.com/science/article/pii/S0965997815000113.

R. Hedayatzadeh, F. Akhavan Salmassi, M. Keshtgari, R. Akbari, and K. Ziarati. Termite colony optimization: A novel approach for optimizing continuous problems. In *2010 18th Iranian Conference on Electrical Engineering*, pages 553–558, 2010.

Adamu Murtala Zungeru, Li-Minn Ang, and Kah Phooi Seng. Termite-hill: Performance optimized swarm intelligence based routing algorithm for wireless sensor networks. *Journal of Network and Computer Applications*, 35(6):1901 – 1917, 2012. ISSN 1084-8045. doi:https://doi.org/10.1016/j.jnca.2012.07.014. URL http://www.sciencedirect.com/science/article/pii/S108480451200166X.

Sascha Häckel and Patrick Dippold. The bee colony-inspired algorithm (bcia): A two-stage approach for solving the vehicle routing problem with time windows. In *Proceedings of the 11th Annual Conference on Genetic and Evolutionary Computation, GECCO ’09*, pages 25–32, New York, NY, USA, 2009. Association for Computing Machinery. ISBN 9781605583259. doi:10.1145/1569901.1569906. URL https://doi.org/10.1145/1569901.1569906.

Dušan Teodorović. *Bee colony optimization (BCO)*, volume 248, chapter 3, pages 39–60. Springer, 2009. doi:10.1007/978-3-642-04225-6_3.

Nicanor Quijano and Kevin Passino. Honey bee social foraging algorithms for resource allocation: Theory and application. *Engineering Applications of Artificial Intelligence*, 23:845–861, 2010. doi:10.1016/j.engappai.2010.05.004

Sunil Nakrani and Craig Tovey. On honey bees and dynamic server allocation in internet hosting centers. *Adaptive Behavior*, 12(3-4):223–240, 2004. doi:10.1177/105971230401200308. URL https://doi.org/10.1177/105971230401200308.

Tomoya Sato and Masafumi Hagiwara. Bee system: Finding solution by a concentrated search. *Proceedings of the IEEE International Conference on Systems, Man and Cybernetics*, 4:3954–3959, December 1997. ISSN 0884-3627. Proceedings of the 1997 IEEE International Conference on Systems, Man, and Cybernetics. Part 3 (of 5); Conference date: 12-10-1997 Through 15-10-1997.

R. D. Maia, L. N. d. Castro, and W. M. Caminhas. Optbees - a bee-inspired algorithm for solving continuous optimization problems. In *2013 BRICS Congress on Computational Intelligence and 11th Brazilian Congress on Computational Intelligence*, pages 142–151, 2013.
H. A. Abbass. Mbo: marriage in honey bees optimization-a haplometrosis polygynous swarming approach. In *Proceedings of the 2001 Congress on Evolutionary Computation (IEEE Cat. No.01TH8546)*, volume 1, pages 207–214 vol. 1, 2001.

Sung Hoon Jung. Queen-bee evolution for genetic algorithms. *Electronics Letters*, 39(6):575–576, 2003.

Xin-She Yang. Engineering optimization via nature-inspired virtual bee algorithms. In *Artificial Intelligence and Knowledge Engineering Applications: A bioinspired Approach. IWINAC 2005*, pages 317–323. Lecture Notes in Computer Science, 6 2005. doi:10.1007/11499305_33

Seyedali Mirjalili. Dragonfly algorithm: a new meta-heuristic optimization technique for solving single-objective, discrete, and multi-objective problems. *Neural Computing and Applications*, 27(4):1053–1073, 2016.

Wen-Tsao Pan. A new fruit fly optimization algorithm: Taking the financial distress model as an example. *Knowledge-Based Systems*, 26:69 – 74, 2012. ISSN 0950-7051. doi:https://doi.org/10.1016/j.knosys.2011.07.001. URL http://www.sciencedirect.com/science/article/pii/S0950705111001365

M. M. al-Rifaie. Dispersive flies optimisation. In 2014 Federated Conference on Computer Science and Information Systems, pages 529–538, 2014.

Jean-Paul M. Arnaout. Worm optimization: A novel optimization algorithm inspired by c. elegans. In *Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management*, pages 2499–2505, 2014.

A. Kumar, R. K. Misra, and D. Singh. Butterfly optimizer. In *2015 IEEE Workshop on Computational Intelligence: Theories, Applications and Future Directions (WCI)*, pages 1–6, 2015.

Sankalap Arora and Satvir Singh. Butterfly optimization algorithm: a novel approach for global optimization. *Soft Computing*, 03 2018a. doi:10.1007/s00500-018-3102-4

Xiangbo Qi, Yunlong Zhu, and Hao Zhang. A new meta-heuristic butterfly-inspired algorithm. *Journal of Computational Science*, 23, 06 2017. doi:10.1016/j.jocs.2017.06.003

Sankalap Arora and Satvir Singh. Butterfly optimization algorithm: a novel approach for global optimization. *Soft Computing*, 03 2018b. doi:10.1007/s00500-018-3102-4

Xiangyuan Jiang and Shuai Li. BAS: beetle antennae search algorithm for optimization problems. *CoRR*, abs/1710.10724, 2017. URL http://arxiv.org/abs/1710.10724.

Nikos Ath. Kallioras, Nikos D. Lagaros, and Dimitrios N. Avtzis. Pity beetle algorithm: A new metaheuristic inspired by the behavior of bark beetles. *Advances in Engineering Software*, 121:147–166, 2018. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2018.04.007. URL https://www.sciencedirect.com/science/article/pii/S0965997817305239

J. Yang, T. Chen, Peng Wang, Zhouquan Zhu, and Shuai Huang. Seven-spot ladybird optimization: A novel and efficient metaheuristic algorithm for numerical optimization. *The Scientific World Journal*, 2013:378515, 2013.

Xin-She Yang. Firefly algorithms for multimodal optimization. In *Stochastic Algorithms: Foundations and Applications. SAGA 2009. Lecture Notes in Computer Science*, volume 5792, pages 169–178, 03 2010. doi:10.1007/978-3-642-04944-6_14

Daniel Oliveira, Rafael Parpinelli, and Heitor Lopes. *Bioluminescent Swarm Optimization Algorithm*, chapter 5. InTech, 04 2011. ISBN 978-953-307-171-8. doi:10.5772/15989

Erik Cuevas, Miguel Cienfuegos, Daniel Zaldívar, and Marco Pérez-Cisneros. A swarm optimization algorithm inspired in the behavior of the social-spider. *Expert Systems with Applications*, 40(16):6374 – 6384, 2013. ISSN 0957-4174. doi:https://doi.org/10.1016/j.eswa.2013.05.041. URL http://www.sciencedirect.com/science/article/pii/S0957417413003394

James J.Q. Yu and Victor O.K. Li. A social spider algorithm for global optimization. *Applied Soft Computing*, 30:614 – 627, 2015. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2015.02.014. URL http://www.sciencedirect.com/science/article/pii/S1568494615001052

Vahideh Hayyolalam and Ali Asghar Pourhaji Kazem. Black widow optimization algorithm: A novel meta-heuristic approach for solving engineering optimization problems. *Engineering Applications of Artificial Intelligence*, 87:103249. 2020. ISSN 0952-1976. doi:https://doi.org/10.1016/j.engappai.2019.103249. URL http://www.sciencedirect.com/science/article/pii/S0952197619302283

Pedro Pinto, Thomas Runkler, and J. Sousa. Wasp swarm optimization of logistic systems, pages 264–267. Springer, 01 2005. doi:10.1007/3-211-27389-1_63

J. Meyer and S. W. Wilson. *Task differentiation in Polistes wasp colonies: a model for self-organizing groups of robots*, pages 346–355. IEEE, 1991.
K. N. Krishnanand and D. Ghose. Glowworm swarm optimization for simultaneous capture of multiple local optima of multimodal functions. *Swarm Intelligence*, 3(2):87–124, 2009.

Shahrzad Saremi, Seyedali Mirjalili, and Andrew Lewis. Grasshopper optimisation algorithm: Theory and application. *Advances in Engineering Software*, 105:30–47, 2017. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2017.01.004 URL http://www.sciencedirect.com/science/article/pii/S0965997816305646

S. Chen. Locust swarms - a new multi-optima search technique. In 2009 *IEEE Congress on Evolutionary Computation*, pages 1745–1752, 2009a.

T. C. Havens, C. J. Spain, N. G. Salmon, and J. M. Keller. Roach infestation optimization. In 2008 *IEEE Swarm Intelligence Symposium*, pages 1–7, Sept 2008. doi:10.1109/SIS.2008.4668317

P. Agarwal, V. Bhatnagar, S. Balochian, Y. Zhang, I. C. Obagwuwa, and A. O. Adewumi. An improved cockroach swarm optimization. *The Scientific World Journal*, 2014:375358, 2014. doi:[10.1155/2014/375358](https://doi.org/10.1155/2014/375358)

Gai-Ge Wang, Suash Deb, and Zhihua Cui. Monarch butterfly optimization. *Neural Computing and Applications*, 2015. doi:10.1007/s00521-015-1923-y.

Murat Canayaz and Ali Karci. Cricket behaviour-based evolutionary computation technique in solving engineering optimization problems. *Applied Intelligence*, 44, 08 2015. doi:10.1007/s10489-015-0706-6

Yannis Marinakis, Magdalene Marinaki, and Nikolaos Matsatsinis. A hybrid bumble bees mating optimization - grasp algorithm for clustering. In *Proceedings of the 4th International Conference on Hybrid Artificial Intelligence Systems*, HAIS ’09, page 549?556, Berlin, Heidelberg, 2009. Springer-Verlag. ISBN 9783642023187. doi:10.1007/978-3-642-02319-4_66 URL https://doi.org/10.1007/978-3-642-02319-4_66

Konstantinos Zervoudakis and Stelios Tsafarakis. A mayfly optimization algorithm. *Computers & Industrial Engineering*, 145:106559, 2020. ISSN 0360-8352. doi:10.1016/j.cie.2020.106559 URL http://www.sciencedirect.com/science/article/pii/S036083522030293X

Xiang Feng, Xiaoting Liu, and Huiqun Yu. Group mosquito host-seeking algorithm. *Applied Intelligence*, 44, 11 2015. doi:10.1007/s10489-015-0718-2

Fayyaz ul Amir Afsar Minhas and Muhammad Arif. Mox: A novel global optimization algorithm inspired from oviposition site selection and egg hatching inhibition in mosquitoes. *Applied Soft Computing*, 11(8):4614 – 4625, 2011. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2011.07.020 URL http://www.sciencedirect.com/science/article/pii/S156849461100281X

M. Alauddin. Mosquito flying optimization (mfo). In 2016 *International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)*, pages 79–84, 2016.

Dervis Karaboga and Bahriye Basturk. A powerful and efficient algorithm for numerical function optimization: artificial bee colony (abc) algorithm. *Journal of Global Optimization*, 39(3):459–471, Nov 2007. ISSN 1573-2916. doi:10.1007/s10898-007-9149-x URL https://doi.org/10.1007/s10898-007-9149-x

Mario Andres Munoz Acosta, Jesus Lopez, and Eduardo Caicedo Bravo. An artificial beehive algorithm for continuous optimization. *International Journal of Intelligent Systems*, 24:1080–1093, 11 2009. doi:10.1002/int.20376

Horst Wedde, Muddassar Farooq, and Yue Zhang. Beehive: An efficient fault-tolerant routing algorithm inspired by honey bee behavior. In *Ant Colony Optimization and Swarm Intelligence*, ANTS 2004. Lecture Notes in Computer Science, pages 83–94, 09 2004. doi:10.1007/978-3-540-28646-2_8

Seyedali Mirjalili. Moth-flame optimization algorithm: A novel nature-inspired heuristic algorithm. *Knowledge-Based Systems*, 89:228 – 249, 2015b. ISSN 0950-7051. doi:10.1016/j.knosys.2015.07.006 URL http://www.sciencedirect.com/science/article/pii/S0950705115002580

Xin She Yang and Amir Hossein Gandomi. Bat algorithm: a novel approach for global engineering optimization. *Engineering Computations*, 29:464–483, 2012. doi:10.1108/02644401211235834

Behnam Malakooti, Hyun Kim, and Shaya Sheikh. Bat intelligence search with application to multi-objective multiprocessor scheduling optimization. *The International Journal of Advanced Manufacturing Technology*, 60, 06 2011. doi:10.1007/s00170-011-3649-z

Mohammed Ali Tawfique. Intelligent algorithm for optimum solutions based on the principles of bat sonar. *CoRR*, abs/1211.0730, 2012. URL http://arxiv.org/abs/1211.0730

C. Subramanian, A.S.S. Sekar, and K. Subramanian. A new engineering optimization method: African wild dog algorithm. *International Journal of Soft Computing*, 8:163–170, 01 2013. doi:10.3923/ijsc.2013.163.170
Rafat Alshorman. A new efficient meta-heuristic optimization algorithm inspired by wild dog packs. *International journal of Hybrid information technology*, 7:83–100, 11 2014. doi:10.14257/ijhit.2014.7.6.07

Gaurav Dhiman and Vijay Kumar. Spotted hyena optimizer: A novel bio-inspired based metaheuristic technique for engineering applications. *Advances in Engineering Software*, 114:48 – 70, 2017. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2017.05.014 URL http://www.sciencedirect.com/science/article/pii/S0965997816305567

Juliano Pierzan, Gabriel Maidl, Eduardo Massashi Yamao, Leandro dos Santos Coelho, and Viviana Cocco Mariani. Cultural coyote optimization algorithm applied to a heavy duty gas turbine operation. *Energy Conversion and Management*, 199:111932, 2019. ISSN 0196-8904. doi:https://doi.org/10.1016/j.enconman.2019.111932 URL http://www.sciencedirect.com/science/article/pii/S0196890419309239

J. Pierzan and L. Dos Santos Coelho. Coyote optimization algorithm: A new metaheuristic for global optimization problems. In *2018 IEEE Congress on Evolutionary Computation (CEC)*, pages 1–8, 2018.

Seyedali Mirjalili, Seyed Mohammad Mirjalili, and Andrew Lewis. Grey wolf optimizer. *Advances in Engineering Software*, 69:46 – 61, 2014. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2013.12.007. URL http://www.sciencedirect.com/science/article/pii/S0965997813001853

C.-Y Liu, X.-H Yan, and H. Wu. The wolf colony algorithm and its application. *Chinese Journal of Electronics*, 20:212–216, 04 2011.

C. Yang, X. Tu, and J. Chen. Algorithm of marriage in honey bees optimization based on the wolf pack search. In *The 2007 International Conference on Intelligent Pervasive Computing (_ipc 2007)*, pages 462–467, 2007.

R. Tang, S. Fong, X. Yang, and S. Deb. Wolf search algorithm with ephemeral memory. In *Seventh International Conference on Digital Information Management (ICDM 2012)*, pages 165–172, 2012.

Maziar Yazdani and Fariborz Jolai. Lion Optimization Algorithm (LOA): A nature-inspired metaheuristic algorithm. *Journal of Computational Design and Engineering*, 3(1):24–36, 06 2015. ISSN 2288-5048. doi:10.1016/j.jcde.2015.06.003 URL https://doi.org/10.1016/j.jcde.2015.06.003

C. Chen, Y. Tsai, I. Liu, C. Lai, Y. Yeh, S. Kuo, and Y. Chou. A novel metaheuristic: Jaguar algorithm with learning behavior. In *2015 IEEE International Conference on Systems, Man, and Cybernetics*, pages 1595–1600, 2015. doi:10.1109/SMC.2015.282

M Goudhaman. Cheetah chase algorithm (cca): a nature-inspired metaheuristic algorithm. *International Journal of Engineering & Technology*, 7(3):1804–1811, 2018. ISSN 2227-524X. doi:10.14419/ijet.v7i3.18.14616 URL https://www.sciencedepubco.com/index.php/ijet/article/view/14616

Shu-Chuan Chu, Pei-wei Tsai, and Jeng-Shyang Pan. Cat swarm optimization. In Qianga Yang and Geoff Webb, editors, *PRICAI 2006: Trends in Artificial Intelligence*, pages 854–858, Berlin, Heidelberg, 2006. Springer Berlin Heidelberg. ISBN 978-3-540-36668-3.

Bo Wang, XiaoPing Jin, and Bo Cheng. Lion pride optimizer: An optimization algorithm inspired by lion pride behavior. *Science China Information Sciences*, 55(10):2369–2389, 2012.

Dawid Połap and Marcin Wozniak. Polar bear optimization algorithm: Meta-heuristic with fast population movement and dynamic birth and death mechanism. *Symmetry*, 9:203, 09 2017. doi:10.3390/sym9100203

S. Zhangbini Koohi, N. A. W. Abdul Hamid, M. Othman, and G. Ibragimov. Raccoon optimization algorithm. *IEEE Access*, 7:5383–5399, 2019.

Hong Man, Julius Beneoluchi Odili, and Mohd Nizam Mohmad Kahar. Solving the traveling salesman’s problem using the african buffalo optimization. *Computational Intelligence and Neuroscience*, 2016:1510256, 2016.

Anezka Kazikova, Michal Pluhacek, Roman Senkerik, and Adam Viktorin. Proposal of a New Swarm Optimization Method Inspired in Bison Behavior: Proceedings of 23rd International Conference on Soft Computing (MENDEL 2017) Held in Brno, Czech Republic, June 20-22, 2017, pages 146–156. Springer, 01 2019. ISBN 978-3-319-97888-8 13 doi:10.1007/978-3-319-97888-8_13

Ramzy Ali. Novel optimization algorithm inspired by camel traveling behavior. *Iraq J. Electrical and Electronic Engineering*, 12:167–177, 01 2016.

G. Wang, S. Deb, and L. d. S. Coelho. Elephant herding optimization. In *2015 3rd International Symposium on Computational and Business Intelligence (ISCBI)*, pages 1–5, 2015.

S. Deb, S. Fong, and Z. Tian. Elephant search algorithm for optimization problems. In *2015 Tenth International Conference on Digital Information Management (ICDIM)*, pages 249–255, 2015.
Mohit Jain, Vijander Singh, and Asha Rani. A novel nature-inspired algorithm for optimization: Squirrel search algorithm. *Swarm and Evolutionary Computation*, 44:148 – 175, 2019. ISSN 2210-6502. doi:https://doi.org/10.1016/j.swevo.2018.02.013 URL http://www.sciencedirect.com/science/article/pii/S2210650217305229

Farid Miarnaeimi, Gholamreza Azizyan, Naser Shabakhty, and Mohsen Rashki. Flying squirrel optimizer (fso): A novel si-based optimization algorithm for engineering problems. *Iranian Journal of Optimization*, 11:177–205, 12 2019.

Ahmed S. Shamsaldin, Tarik A. Rashid, Rawan A. Al-Rashid Agha, Nawzad K. Al-Salih, and Mokhtar Mohammadi. Donkey and smuggler optimization algorithm: A collaborative working approach to path finding. *Journal of Computational Design and Engineering*, 6(4):562 – 583, 2019.

O˘guz FINDIK. Bull optimization algorithm based on genetic operators for continuous optimization problems. *TURKISH JOURNAL OF ELECTRICAL ENGINEERING & COMPUTER SCIENCES*, 23:2225–2239, 01 2015. doi:10.3906/elk-1307-123

Amir Mohammad Fathollahi-Fard, Mostafa Hajiaghaei-Keshteli, and Reza Tavakkoli-Moghaddam. Red deer algorithm (rda): a new nature-inspired meta-heuristic. *Soft Computing*, 2020.

A. Kaveh and N. Farhoudi. A new optimization method: Dolphin echolocation. *Advances in Engineering Software*, 59:53 – 70, 2013. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2013.03.004 URL http://www.sciencedirect.com/science/article/pii/S0965997813000318

Jianqiang Zhao, Kao Ge, , and Kangyao Xu. A heuristic algorithm based on leadership strategy: Leader of dolphin herd algorithm (ldha). *Journal of Advanced Computational Intelligence and Intelligent Informatics*, 19(4):491–499, 2015. doi:10.20965/jaciii.2015.p0491

Y. Shiqin, J. Jianjun, and Y. Guangxing. A dolphin partner optimization. In *2009 WRI Global Congress on Intelligent Systems*, volume 1, pages 124–128, May 2009. doi:10.1109/GCIS.2009.464

A. Serani and M. Diez. Dolphin pod optimization - a nature-inspired deterministic algorithm for simulation-based design. In *MOD. Machine Learning, Optimization, and Big Data: Second International Workshop, MOD 2017*. Springer International Publishing., 2017.

Seyedali Mirjalili and Andrew Lewis. The whale optimization algorithm. *Advances in Engineering Software*, 95:51 – 67, 2016. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2016.01.008 URL http://www.sciencedirect.com/science/article/pii/S0965997816300163

A. Ebrahimi and E. Khamehchi. Sperm whale algorithm: An effective metaheuristic algorithm for production optimization problems. *Journal of Natural Gas Science and Engineering*, 29:211 – 222, 2016. ISSN 1875-5100. doi:https://doi.org/10.1016/j.jngse.2016.01.001 URL http://www.sciencedirect.com/science/article/pii/S187551001630014

Totok R. Biyanto, Matradji, Sonny Irawan, Henoky Y. Febrianto, Naindar Afdanny, Ahmad H. Rahman, Kevin S. Gunawan, Januar A.D. Pratama, and Titania N. Bethiana. Killer whale algorithm: An algorithm inspired by the life of killer whale. *Procedia Computer Science*, 124:151–157, 2017. ISSN 1877-0509. doi:https://doi.org/10.1016/j.procs.2017.12.141 URL http://www.sciencedirect.com/science/article/pii/S1877050917329095

Maha Mahmood and Belal Al-Khateeb. The blue monkey: A new nature inspired metaheuristic optimization algorithm. *Periodicals of Engineering and Natural Sciences (PEN)*, 7:1054–1066, 09 2019.

Jagdish Chand Bansal, Harish Sharma, Shimpl Singh Jadon, and Maurice Clerc. Spider monkey optimization algorithm for numerical optimization. *Memetic Computing*, 6(1):31–47, 2014. doi:10.1007/s12293-013-0128-0 URL https://doi.org/10.1007/s12293-013-0128-0

M. Khishe and M.R. Mosavi. Chimp optimization algorithm. *Expert Systems with Applications*, 149:113338, 2020. ISSN 0957-4174. doi:https://doi.org/10.1016/j.eswa.2020.113338 URL http://www.sciencedirect.com/science/article/pii/S0957417420301639

T. Chen, Y. Wang, L. Pang, W. Jia, Z. Liu, and X. Wei. Artificial tribe algorithm for solving constrained optimization problems. In *2010 IEEE International Conference on Intelligent Computing and Intelligent Systems*, volume 2, pages 179–182, 2010.
A 2020 Taxonomy of living beings behavior algorithms

Arit Thammano and Jittraporn Moolwong. A new computational intelligence technique based on human group formation. Expert Systems with Applications, 37(2):1628 – 1634, 2010. ISSN 0957-4174. doi:https://doi.org/10.1016/j.eswa.2009.06.046

L. M. Zhang, C. Dahlmann, and Y. Zhang. Human-inspired algorithms for continuous function optimization. In 2009 IEEE International Conference on Intelligent Computing and Intelligent Systems, volume 1, pages 318–321, 2009.

L. Ashby R. Yampolskiy and L. Hassan. Wisdom of artificial crowds? a metaheuristic algorithm for optimization. Journal of Intelligent Learning Systems and Applications, 4(2):98–107, 2012. doi:10.4236/jilsa.2012.42009

Mohammad Taherdangkoo, Mohammad Hossein Shirzadi, Mehran Yazdi, and Mohammad Hadi Bagheri. A robust clustering method based on blind, naked mole-rats (bnmr) algorithm. Swarm and Evolutionary Computation, 10:1 – 11, 2013. ISSN 2210-6502. doi:https://doi.org/10.1016/j.swevo.2013.01.001

Ahmed Al-Obaidi, Hasanen Abdullah, and Zied Othman. Meerkat clan algorithm: A new swarm intelligence algorithm. Indonesian Journal of Electrical Engineering and Computer Science, 10, 04 2018.

Carlos Eduardo Klein and Leandro dos Santos Coelho. Meerkats-inspired algorithm for global optimization problems. In ESANN, pages 679–684, 2018.

Antonio Mucherino and Onur Seref. Monkey search: a novel metaheuristic search for global optimization. AIP Conference Proceedings, 953(1):162–173, 2007. doi:10.1063/1.2817338

Rohit Salgotra and Urvinder Singh. The naked mole-rat algorithm. Neural Computing and Applications, 31(12):8837–8857, 2019.

Gai-Ge Wang, Xiao-Zhi Gao, Kai Zenger, and Leandro Coelho. A novel metaheuristic algorithm inspired by rhino herd behavior. In Proceedings of The 9th EUROSIM Congress on Modelling and Simulation, EUROSIM 2016. The 57th SIMS Conference on Simulation and Modelling SIMS 2016, pages 1026–1033, 12 2018. doi:10.3384/ecp171421026

K. Nara, T. Takeyama, and Hyungchul Kim. A new evolutionary algorithm based on sheep flocks heredity model and its application to scheduling problem. In IEEE SMC’99 Conference Proceedings. 1999 IEEE International Conference on Systems, Man, and Cybernetics (Cat. No.99CH37028), volume 6, pages 503–508 vol.6, 1999.

Mohammad Mahdi Motevali, Ali Mohammad Shanghooshabad, Reza Zohouri Aram, and Hamidreza Keshavarz. Who: A new evolutionary algorithm bio-inspired by wildebeests with a case study on bank customer segmentation. International Journal of Pattern Recognition and Artificial Intelligence, 33(05):1959017, 2019.

Adel Eesa, Adnan Mohsin Abdulazeez, and Zeynep Orman. Cuttlefish algorithm : A novel bio-inspired optimization algorithm. International Journal of Scientific & Engineering Research, 4:1978–1986, 06 2013.

Amir Hossein Gandomi and Amir Hossein Alavi. Krill herd: A new bio-inspired optimization algorithm. Communications in Nonlinear Science and Numerical Simulation, 17(12):4831 – 4845, 2012. ISSN 1007-5704. doi:https://doi.org/10.1016/j.cnsns.2012.05.010

Jing An, Qi Kang, Lei Wang, and Qidi Wu. Mussels wandering optimization: An ecologically inspired algorithm for global optimization. Cognitive Computation, 5(2):188–199, 2013.

Seyed Ali Mirjalili, Amir H. Gandomi, Seyedeh Zahra Mirjalili, Shahrooz Saremi, Hossam Faris, and Seyed Mohammad Mirjalili. Salp swarm algorithm: A bio-inspired optimizer for engineering design problems. Advances in Engineering Software, 114:163 – 191, 2017. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2017.07.002

Chun-Wei Tsai, S. Salcedo-Sanz, J. Del Ser, I. Landa-Torres, S. Gil-López, and J. A. Portilla-Figueras. The coral reefs optimization algorithm: A novel metaheuristic for efficiently solving optimization problems. The Scientific World Journal, 2014:739768, 2014.

A. Mutazono, M. Sugano, and M. Murata. Frog call-inspired self-organizing anti-phase synchronization for wireless sensor networks. In 2009 2nd International Workshop on Nonlinear Dynamics and Synchronization, pages 81–88, 2009.

Muzaffar Eusuff, Kevin Lansey, and Fayzul Pasha. Shuffled frog-leaping algorithm: a memetic meta-heuristic for discrete optimization. Engineering Optimization, 38(2):129–154, 2006. doi:10.1080/03052150500384759
Oscar Maciel C., Erik Cuevas, Mario A. Navarro, Daniel Zaldívar, and Salvador Hinojosa. Side-blotched lizard algorithm: A polymorphic population approach. Applied Soft Computing, 88:106039, 2020. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2019.106039. URL http://www.sciencedirect.com/science/article/pii/S156849461930821X

F. García and José Moreno-Pérez. Jumping frogs optimization: A new swarm method for discrete optimization. Documentos de trabajo del DEIOC N 3/2008 Universidad de la Laguna, 01 2008.

Min-Yuan Cheng and Doddy Prayogo. Symbiotic organisms search: A new metaheuristic optimization algorithm. Computers & Structures, 139-98 – 112, 2014. ISSN 0045-7949. doi:https://doi.org/10.1016/j.compstruc.2014.03.007. URL http://www.sciencedirect.com/science/article/pii/S0045794914000881

S. Su, J. Wang, W. Fan, and X. Yin. Good lattice swarm algorithm for constrained engineering design optimization. In 2007 International Conference on Wireless Communications, Networking and Mobile Computing, pages 6421–6424, 2007.

Pinar Civicioglu. Artificial cooperative search algorithm for numerical optimization problems. Information Sciences, 229:58 – 76, 2013. ISSN 0020-0255. doi:https://doi.org/10.1016/j.ins.2012.11.013. URL http://www.sciencedirect.com/science/article/pii/S0020025512007669

S. Mohseni, R. Gholami, N. Zarei, and A. R. Zadeh. Competition over resources: A new optimization algorithm based on animals behavioral ecology. In 2014 International Conference on Intelligent Networking and Collaborative Systems, pages 311–315, 2014.

Luis A. Márquez-Vega and Luis M. Torres-Treviño. Universal swarm optimizer for multi-objective functions. In Ildar Batyrshin, María de Lourdes Martínez-Villaseñor, and Hiram Eredin Ponce Espinosa, editors, Advances in Soft Computing, pages 50–61, Cham, 2018. Springer International Publishing. ISBN 978-3-030-04491-6.

Aura Reggiani, Hanning Chen, Yunlong Zhu, Kunyuan Hu, and Xiaoxian He. Hierarchical swarm model: A new approach to optimization. Discrete Dynamics in Nature and Society, 2010:379649, 2010. doi:10.1155/2010/379649. URL https://doi.org/10.1155/2010/379649

S. He, Q. H. Wu, and J. R. Saunders. A novel group search optimizer inspired by animal behavioural ecology. In 2006 IEEE International Conference on Evolutionary Computation, pages 1272–1278, 2006.

T. Chen. A simulative bionic intelligent optimization algorithm: Artificial searching swarm algorithm and its performance analysis. In 2009 International Joint Conference on Computational Sciences and Optimization, volume 2, pages 864–866, 2009b.

Carlo Piccardi, Erik Cuevas, Mauricio González, Daniel Zaldívar, Marco Pérez-Cisneros, and Guillermo García. An algorithm for global optimization inspired by collective animal behavior. Discrete Dynamics in Nature and Society, 2012:638275, 2012.

Xiaohui Cui, Jinzhu Gao, and Thomas E. Potok. A flocking based algorithm for document clustering analysis. Journal of Systems Architecture, 52(8):505 – 515, 2006. ISSN 1383-7621. doi:https://doi.org/10.1016/j.sysarc.2006.02.003. URL http://www.sciencedirect.com/science/article/pii/S1383762106000191

R. Oftadeh and M. J. Mahjoob. A new meta-heuristic optimization algorithm: Hunting search. In 2009 Fifth International Conference on Soft Computing, Computing with Words and Perceptions in System Analysis, Decision and Control, pages 1–5, 2009.

Surafel Tilahun, Choon Hong, and Hong Choon Ong. Prey-predator algorithm: A new metaheuristic algorithm for optimization problems. International Journal of Information Technology & Decision Making, 14, 12 2015. doi:10.1142/S021962201450031X.

Xiangtao Li, Jie Zhang, and Minghao Yin. Animal migration optimization: an optimization algorithm inspired by animal migration behavior. Neural Computing and Applications, 24(7):1867–1877, 2014. doi:10.1007/s00521-013-1433-8. URL https://doi.org/10.1007/s00521-013-1433-8

H. Chen and J. Wang. An improved population migration algorithm for the prediction of protein folding. In Advances in Neural Networks ? ISNN 2009. ISNN 2009. Lecture Notes in Computer Science. Springer, 2009. URL https://doi.org/10.1007/978-3-642-01513-7_72

Zelinka I. SOMA-Self-Organizing Migrating Algorithm. In: New Optimization Techniques in Engineering, volume 141, pages 167–217. Springer Berlin Heidelberg. Berlin, Heidelberg, 2004.

Tai-Chen Chen, Pei-Wei Tsai, Shu-Chuan Chu, and Jeng-Shyang Pan. A novel optimization approach: Bacterial-ga foraging. In Second International Conference on Innovative Computing, Information and Control (ICICIC 2007), pages 391–391, 2007. doi:10.1109/ICICIC.2007.67.
Binggen Zhang, Ben Niu, and Hong Wang. Bacterial colony optimization. *Discrete Dynamics in Nature and Society*, 2012:698057, 2012.

S. Das, A. Chowdhury, and A. Abraham. A bacterial evolutionary algorithm for automatic data clustering. In *2009 IEEE Congress on Evolutionary Computation*, pages 2403–2410, 2009.

K. M. Passino. Biomimicry of bacterial foraging for distributed optimization and control. *IEEE Control Systems Magazine*, 22(3):52–67, June 2002. ISSN 1066-033X. doi:10.1109/MCS.2002.1004010

Ying Chu, Hua Mi, Huilian Liao, Zhen Ji, and Q. H. Wu. A fast bacterial swarming algorithm for high-dimensional function optimization. In *2008 IEEE Congress on Evolutionary Computation (IEEE World Congress on Computational Intelligence)*, pages 3135–3140, 2008.

Chandramouli Anandaraman, Arun Sankar, and Ramaraj Natarajan. A new evolutionary algorithm based on bacterial evolution and its application for scheduling a flexible manufacturing system. *Jurnal Teknik Industri*, 14, 06 2012. doi:10.9744/jti.14.1.1-12

S. D. Muller, J. Marchetto, S. Airaghi, and P. Kournoutsakos. Optimization based on bacterial chemotaxis. *IEEE Transactions on Evolutionary Computation*, 6(1):16–29, 2002.

H. Mo and L. Xu. Magnetotactic bacteria optimization algorithm for multimodal optimization. In *2013 IEEE Symposium on Swarm Intelligence (SIS)*, pages 240–247, 2013.

M. Bidar, H. R. Kanan, M. Mouhoub, and S. Sadaoui. Mushroom reproduction optimization (mro): A novel nature-inspired evolutionary algorithm. In *2018 IEEE Congress on Evolutionary Computation (CEC)*, pages 1–10, 2018.

Xiaoming Zhang, Bingyu Sun, Tao Mei, and Rujing Wang. Post-disaster restoration based on fuzzy preference relation and bean optimization algorithm. In *2010 IEEE Youth Conference on Information, Computing and Telecommunications*, pages 271–274, 11 2010. doi:10.1109/YCICT.2010.5713097

Jun Li, Zhihua Cui, and Zhongzhi Shi. An improved artificial plant optimization algorithm for coverage problem in wsn. *Sensor Letters*, 10(8):1874–1878, 2012. doi:10.1166/sl.2012.2627

Manizheh Ghaemi and Mohammad-Reza Feizi-Derakhshi. Forest optimization algorithm. *Expert Systems with Applications*, 41(15):6676 – 6687, 2014. ISSN 0957-4174. doi:https://doi.org/10.1016/j.eswa.2014.05.009 URL http://www.sciencedirect.com/science/article/pii/S0957417414002899

W. Cai, W. Yang, and X. Chen. A global optimization algorithm based on plant growth theory: Plant growth optimization. In *2008 International Conference on Intelligent Computation Technology and Automation (ICICTA)*, volume 1, pages 1194–1199, 2008.

Farshad Merrikh-Bayat. A numerical optimization algorithm inspired by the strawberry plant. *CoRR*, abs/1407.7399, 2014. URL http://arxiv.org/abs/1407.7399

A.R. Mehrabian and C. Lucas. A novel numerical optimization algorithm inspired from weed colonization. *Ecological Informatics*, 1(4):355 – 366, 2006. ISSN 1574-9541. doi:https://doi.org/10.1016/j.ecoinf.2006.07.003 URL http://www.sciencedirect.com/science/article/pii/S1574954106000665

Upeka Premaratne, Jagath Samarabandu, and Tarlochan Sidhu. A new biologically inspired optimization algorithm. In *2009 International Conference on Industrial and Information Systems (ICIIS)*, pages 279–284, 2009. doi:10.1109/ICIINFS.2009.5429852

Camilo Caraveo, Fevier Valdez, and Oscar Castillo. A new optimization meta-heuristic algorithm based on self-defense mechanism of the plants with three reproduction operators. *Soft Computing*, 22(15):4907–4920, 2018.

María Isabel Herreros, Xiaoxian He, Hanning Chen, Ben Niu, and Jie Wang. Root growth optimizer with self-similar propagation. *Mathematical Problems in Engineering*, 2015:498626, 2015.

Yacine Labbi, Djilani Ben Attous, Hossam A. Gabbar, Belkacem Mahdad, and Aboelsood Zidan. A new rooted tree optimization algorithm for economic dispatch with valve-point effect. *International Journal of Electrical Power & Energy Systems*, 79:298 – 311, 2016. ISSN 0142-0615. doi:https://doi.org/10.1016/j.ijepes.2016.01.028 URL http://www.sciencedirect.com/science/article/pii/S0142061516000405

F. Merrikh-Bayat. The runner-root algorithm: A metaheuristic for solving unimodal and multimodal optimization problems inspired by runners and roots of plants in nature. *Applied Soft Computing*, 33:292 – 303, 2015. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2015.04.048 URL http://www.sciencedirect.com/science/article/pii/S1568494615002756

Xin-She Yang. Flower pollination algorithm for global optimization. *Lecture Notes in Computer Science*, page 240?249, 2012. ISSN 1611-3349. doi:10.1007/978-3-642-32894-7_27 URL http://dx.doi.org/10.1007/978-3-642-32894-7_27
H. Moez, A. Kaveh, and N. Taghizadieh. Natural forest regeneration algorithm: A new meta-heuristic. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 40(4):311–326, 2016.

Abdel Salhi and Eric Fraga. Nature-inspired optimisation approaches and the new plant propagation algorithm. In *Proceeding of The International Conference on Numerical Analysis and Optimization (ICeMATH2011)*, 06 2011. doi:10.13140/2.1.3262.0806

Ali Karci and Bilal Alatas. Thinking capability of saplings growing up algorithm. In *Intelligent Data Engineering and Automated Learning ? IDEAL 2006*, pages 386–393, 09 2006. doi:10.1007/11875581_47

Xinyu Li, Muhammad Sulaiman, and Abdellah Salhi. A seed-based plant propagation algorithm: The feeding station model. *The Scientific World Journal*, 2015:904364, 2015. URL https://doi.org/10.1155/2015/904364

Sait Ali Uymaz, Gulay Tezel, and Esra Yel. Artificial algae algorithm (aaa) for nonlinear global optimization. *Applied Soft Computing*, 31:153 – 171, 2015. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2015.03.003 URL http://www.sciencedirect.com/science/article/pii/S1568494615001465

D. R. Monismith and B. E. Mayfield. Slime mold as a model for numerical optimization. In *2008 IEEE Swarm Intelligence Symposium*, pages 1–8, Sep. 2008. doi:10.1109/SIS.2008.4668295

Xiaoge Zhang, Y. Zhang, Z. Zhang, and Y. Deng. A method to solve shortest path finding in directed graph based on an amoeboid organism. In *2012 24th Chinese Control and Decision Conference (CCDC)*, pages 3699–3702, 2012.

Pablo Cortés, José M. García, Jesús Munuzuri, and Luis Onieva. Viral systems: A new bio-inspired optimisation approach. *Computers & Operations Research*, 35(9):2840 – 2860, 2008. ISSN 0305-0548. doi:https://doi.org/10.1016/j.cor.2006.12.018 URL http://www.sciencedirect.com/science/article/pii/S0305054806003182 Part Special Issue: Bio-inspired Methods in Combinatorial Optimization.

Mu Dong Li, Hui Zhao, Xing Wei Weng, and Tong Han. A novel nature-inspired algorithm for optimization: Virus colony search. *Advances in Engineering Software*, 92:65 – 88, 2016. ISSN 0965-9978. doi:https://doi.org/10.1016/j.advengsoft.2015.11.004 URL http://www.sciencedirect.com/science/article/pii/S0965997815001702

Yun-Chia Liang and Josue Rodolfo Cuevas Juarez. A novel metaheuristic for continuous optimization problems: Virus optimization algorithm. *Engineering Optimization*, 48(1):73–93, 2016. doi:10.1080/0305215X.2014.994868 URL https://doi.org/10.1080/0305215X.2014.994868

Morteza Jaderyan and Hassan Khotanlou. Virulence optimization algorithm. *Applied Soft Computing*, 43:596 – 618, 2016. ISSN 1568-4946. doi:https://doi.org/10.1016/j.asoc.2016.02.038 URL http://www.sciencedirect.com/science/article/pii/S1568494616300898

F. Martínez-Álvarez, G. Asencio-Cortés, J. F. Torres, D. Gutiérrez-Avilés, L. Melgar-García, R. Pérez-Chacón, C. Rubio-Escudero, J. C. Riquelme, and A. Troncoso. Coronavirus optimization algorithm: A bioinspired metaheuristic based on the covid-19 propagation model. *Big Data*, 8(4):308–322, 2020. doi:10.1089/big.2020.0051 URL https://doi.org/10.1089/big.2020.0051 PMID: 32716641.