Nature-Inspired Algorithms and Smart City Applications

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INTRODUCTION

Information and Communication Technology (ICT) play an important role in ensuring efficient use of resources. Through its influences on businesses and government, the fourth industrial revolution will form the future. People have no control over either technology or the disruption that comes with the fourth industrial revolution (Xu, David and Kim 2018). This disruption will impact every sector of an economy ranging from education, health, finance, energy and many more. Creating a dynamic structure to handle such disruption and ensure optimal resource utilization is imperative towards the creation of smart cities.

As indicated in the Focus section of this chapter, we first introduce nature inspired algorithms, along with their characteristics, and show how they are being used with different entities, along with their interactions, for intelligent management within smart cities. To understand how different entities play a role in a smart city, we first explore the different spheres of the fourth industrial revolution and then explore different aspects of the opportunities, expectations, and challenges of a smart city.

In the rest of this chapter, section 2 first begins with a short overview of nature-inspired algorithms and smart city applications. The focus of the chapter, the use of nature-inspired algorithms within fourth industrial revolution and within smart cities, is given. Consequently, in the next section, the era of the fourth industrial revolution with its cyber, digital, and biological spheres is presented. Within this revolution, the intersection of these spheres are outlined with their emergent technologies that are often assisted by nature-inspired algorithms. To further this focus, the opportunities, expectations, and challenges of the fourth industrial revolution then are presented. The last section concludes this chapter. Key terms and suggestions for further readings follow.

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BACKGROUND

Nature-Inspired Algorithms

These are algorithms inspired from the behavior of social colonies for studying the phenomenology of living systems such as planning, learning, making decisions, perception, etc. The advantage of a Nature-inspired technique is the ability to jump out of any local search that might not lead to an ideal cluster formation. Examples of nature-inspired or bio-inspired techniques are namely Genetic Algorithms (GA), Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Wolf Search Algorithm (WSA), Social Spider Algorithm (SSA) and many more.

Genetic Algorithm (GA) is an evolutionary approach that is based on the concept of "survival of the fittest", where the survival depends on "natural selection" that is when the species considered as weak and cannot adapt to the conditions of the habitat are eliminated whereas the species considered as strong and that can adapt to the habitat survives. Thus, natural selection is based on the notion that strong species have a greater chance to pass their genes to future generations, while weaker species are eliminated by natural selection. Sometimes, there are random changes that occur in genes due to changes within the external environments of species, which will cause new future species that are produced to inherit different genetic characteristics. At the stage of producing new species, individuals are selected, at random, from the current population within the habitat to be parents and use them to produce the children for the next generation, thus successive generations are able to adapt to the habitat in respect of time (Mirjalili, 2019).

Ant Colony Optimization (ACO) is characterised as a nature-inspired method that mimics ants' foraging behaviour in their hunt for the shortest paths to food sources. When a food source is discovered, ants will leave a trail of a chemical pheromone to indicate their path for other ants to travel (Agbehadji et al. 2018). A pheromone trail can be described as an odorous material that is utilised as a way to indirectly communicate among ants. The strength of the pheromone is subject to the quantity, quality of, and distance to the food source. This trail of pheromone is also contingent on time, as the trail will evaporate over time, unless refreshed by new ants traversing the same trail. This evaporation quality of pheromone avoids the issue of ants prematurely converging; consequently, ants are able to explore different trails within their area and find an even shorter, better path than the existing one. In the case of an ant being lost, an ant will travel randomly until it finds a strong pheromone trail. The strength of the trail indicates its optimality. If the trail is optimal, such as shortest distance to a large quality food source, this trail will be strengthened through pheromone deposits by ants as they traverse the trail to the food source. If the trail is less than ideal, the ants adopt the more strongly scented optimal trail and less optimal trails, losing their pheromones by evaporation over time, become less and less attractive. Through their adoption of trails, ants can make probabilistic decisions as to where to deposit their pheromones (Coloroni, 1992).

Swarm Intelligence is a nature-inspired method based on swarm behaviour such as ðsh and bird schools in nature. The swarm behaviour is conveyed with respect to how particles (e.g., Particle Swarm Optimization) adapt and make a decision depending on their position within a search space and neighbouring particles (Agbehadji et al. 2018). The advantage of swarm behaviour is that, as an individual particle arrives at a decision, it leads to emergent behaviour, which is contingent on the local interaction among particles to find a potentially optimal solution. Thus, swarm behaviour guarantees some form of collective intelligence. The author (Reynolds 1987) had suggested a model that mimics the ñocking behaviour of birds founded on three simplified rules namely velocity matching with neighbouring ñockmates, collision avoidance with neighbouring ñockmates, and flock centering to remain close to the