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学 位 論 文 題 目　　Bio-inspired Computational Algorithm and Its Applications to Optimization Problems
(生物にヒントを得た計算アルゴリズムとその最適化問題への応用)

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Abstract

Bio-inspired meta-heuristics are the study of investigating biological mechanisms and thereafter modeling such living mechanisms and theories and their live by computer simulations. A large number of papers have focused on the character is tics of the swarm behaviors, such as birds, particles, fishes, human brains, as well as other insects including mosquitoes, because of their incredible abilities to solve a lot of very practical engineering and optimization problems. These problems are very difficult to be solved and some of those have proved to be NP-hard or NP-complete. That is to say, no polynomial time algorithm can be designed and used to solve such problems.

Based on the above research background, in this thesis, I am devoting to studying a number of meta-heuristics and applying them to solve some important practical problems. Some typical meta-heuristics involving the genetic algorithm, genetic programming, ant colony optimization, particle swarm optimization, differential evolution algorithms, artificial immune algorithms, gravitational search algorithm, and some others which will not be introduced in this thesis in details. Those who are interested in these algorithms may refer to my cited literatures.

The thesis is organized as in the following.

In chapter 1, we first introduced some basic concepts and theories of the bio-inspired meta-heuristics. The mechanisms of the biologically inspirations and the framework of how to design such meta-heuristics are brief summarized and introduced. Moreover, it studies the field consist of all their

social behavior and the connections among their behaviors. Briefly the utilization of simulation by computers to model the living mechanisms and for improve the usage effectiveness of such simulations is important. Bio-inspired meta-heuristics is an interdiscipline which is composed by a lot of different research fields, including computer science, artificial intelligence, applied mathematics, biological theories, physical phenomena, genetics, and some others. The powerful learning abilities and evolutionary capacities of biological systems are motivating us to design more robust and strong computational intelligent systems to solve the practical problems. These problems are becoming much harder to be revolved due to its dynamic environment, complex variable dependent relationships and time-related factors. Thus, the fundamental concepts and related researches of the background, together with the research purpose are summarized in this chapter.

In chapter 2, we focus on bio-inspired meta-heuristics, especially its computational framework. We introduced bio-inspired computations from the following three parts: the most famous Evolutionary computation (EC), the recent developed Ant colony optimization (ACO) and the novel introduced Artificial immune system (AIS). In this chapter, the basic descriptions including their biological inspirations, algorithmic modelling, computational systems and typical applications of EC, ACO, and AIS are presented.

In chapter 3, a new hybrid method by incorporating EDA into IA is proposed in order to solve the TSPs. In this method, EDA is used to realize the information exchanging during different solutions generated by IA through the probabilistic model. Thus, EDA enables IA to be quickly convergent to promising search areas. To refine the solutions sampled by EDA, a heuristic local search operator is also proposed to repair the infeasible solutions, and further facilitate the search by making use of the problem-dependent knowledge of TSP.

In chapter 4, another computational algorithm using particle swarm optimization (PSO) and a probability model (PM was proposed and presented to solve the well-known graph planarization problem (GPP). GPP is a traditional combinatorial optimization problem which is deeply related with circuit board layout problem, VLSI desing, automatic graph drawing problem, and some other graph-based problems. Moreover, it has significant theoretical importance related with networks design and analysis, computational geometry, and some other topological problems. Generally speaking, GPP is required to carry out two tasks involving a maximum planar subgraph acquisition and a plane embedding problem. The former is to find a maximum planar subgraph with a minimum cardinality subset of edges which can be removed from the original graph, and the later is to draw the remaining subgraph on a plane such that no two edges intersect with each other except a common endpoint. The proposed PMPSO has demonstrated to be effective to find near optimal solutions for GPP than the previously proposed methods.

In chapter 5, Ant colony optimization (ACO) is one of the best heuristic algorithms for combinatorial optimization problems. Due to its distinctive search mechanism, ACO can perform successfully on the static traveling salesman problem (TSP). Nevertheless, ACO has some trouble in solving the dynamic TSP (DTSP) since the pheromone of the previous optimal trail attracts ants to follow even if the environment changes. Therefore, the quality of the solution is much inferior to that of the static TSP's solution. In this paper, ant colony algorithm with neighborhood search called NS-ACO is proposed to handle the DTSP composed by random traffic factors. ACO utilizes the short-term memory to increase the diversity of solutions and three moving operations containing swap, insertion and 2-opt optimize the solutions found by ants. The experiments are carried out to evaluate the performance of NS-ACO comparing with the conventional ACS and the ACO with random immigrants (RIACO) on the DTSPs of different scales. The experimental results demonstrate our proposed algorithm outperforms the other algorithms and is a competitive and promising approach to DTSP.

In chapter 6, there are conclusions and future Works. We proposed IA-EDA, PM-PSO and NS-ACO. They can be concluded that these new models can produce better solutions than traditional model before. And in the future, I will go a step further on various kinds of algorithm of Bio-inspired computation. Then, improve the performance of the current existent Bio-inspired computation and apply them to solve engineering problems in new fields. Last but not least, Bio-inspired computation can combine with other computational intelligence algorithms for solving much complex problems.

【学位申請審査結果の要旨】

当学位論文審査委員会は，標記の博士学位申請論文を詳細に査読し，また論文発表会を平成２８年８月２４日(水曜日)に公開で開催し，詳細な質疑を行って論文の審査を行った。ここに，その審査結果の要旨を報告する。

近年，人類自身も含め，自然生物の情報処理システムに関する研究が盛んに行われている。本学位論文では，生物にヒントを得た計算アルゴリズムに着目し，特に，それらのアルゴリズムを組み合わせることで，最適化問題へ応用できることを明らかにするとともに，実際のデータ解析から有効性を示している。

本論文では，３種のアルゴリズム組み合わせに関する検討を行っており，各章にそれぞれの組み合わせに関する検討結果をまとめている。

第３章では，分布推定アルゴリズム（Estimation of Distribution Algorithm: EDA）と人工免疫アルゴリズム（Immune Algorithm: IA）を組み合わせ，巡回セールスマン問題 (Traveling Salesman Problem: TSP)に適用した。実験は，100 000 都市の規模を持つインスタンスで行った。実験結果として，IA-EDA は経路総距離，時間コストを引き下げることが可能であることを示し，その有効性を実証した。

第４章では，粒子群最適化（Particle Swarm Optimization: PSO）のメカニズムと確率モデル（Probability Model: PM）を組み合わせ，画像の平面化問題（Graph Planarization Problem: GPP）適用した。その計算結果は，最適解に収束することを確保した上で，探索空間を縮小し，より有効な特徴量を利用するよう捜索の方向を決め，収束速度を向上させると同時に解の精密度を高めることもできた。これらの結果から，画像の平面化問題を解く際に，非常に良好な実験成果が得られることを示した。

第５章では，蟻コロニー最適化（Ant Colony Optimization: ACO）のメカニズムと原理を近傍探索（Neighborhood Search: NS）アルゴリズムに組み合わせ，動的巡回セールスマン問題 (Dynamic Traveling Salesman Problem: DTSP)に適用した。伝統的な蟻コロニー最適化モデルは，静的巡回セールスマン問題を解決する際は問題ないが，動的巡回セールスマン問題（都市数が変化する場合，重みの行列が変化した場合など）を解決出来ない場合がある。NS－ACO は，動的巡回セールスマン問題を解決する場合に，蟻コロニー最適化での優良な初期の解から，近傍探索により局所の探索能力を強化して，収束速度を高めることを達成した。実験の結果からも，新しい計算方法の有効性及び高速性が証明された。

以上要するに本論文は，従来は単一で用いられていたアルゴリズムに関して，それらを組み合わせる手法を提案し，シミュレーション実験を通してそれら組

み合わせアルゴリズムの有効性を示したものであり，提案したモデルは非常に高性能であることから，工学的応用のみならず，学術的にも価値が高い。
　よって，当博士論文審査委員会は本博士学位申請論文が博士の学位を授与することに十分値するものと認め，合格と判断した。