Advance ACS Using Chaos Searching Technique (Case Study: ACS-Based Network Routing Algorithms)

تحسين نظام مستعمرات النمل بأستخدام تقنية البحث الفوضوية (حالة دراسية : خوارزميات التوجيه الشبكية المعتمدة على نظام مستعمرات النمل)

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Abstract

In this paper a hybrid algorithm by combining the Ant Colony System (ACS) with Chaos Search (CS) is presented to enhance ACS (case study ACS-based network routing algorithms). The hybrid algorithm is injecting CS into ACS by initializing the algorithm with a set of random ants that travels in search space from source to destination. Then an optimization is obtained by CS to distinguish whither ant is feasible or not. That proposed model called (H-T-S-C). In each of iterations all feasible ants are ranked in ascending order. Ants in the front of the list are updated by ACS, while ants in the end of list are updated by CS. CS used here is not only to enhance the ants but also to improve the diversity of ant swarm so as to avoid ACS trapping the local optima. The results showed that the hybrid algorithm increased Message Delivery Ratio (MDR) about 10%, decreased jitter about 10%, decreased congestion about 5% and decreased time of search about 3%.

Keywords: Chaos Search, ACS, Stagnation, Hybrid Algorithm, Network Routing Algorithm.

الخلاصة

في هذا البحث تم اقتراح خوارزمية هجينة تدمج نظام مستعمرات النمل من تقنية البحث الفوضوي لتحسين نظام مستعمرات النمل (وكحال دراسية تم تطبيق المقترح على خوارزميات التوجيه الشبكية المعتمدة عل نظام مستعمرات النمل). الخوارزمية الهجينة هي حقن البحث الفوضوي الى نظام مستعمرات النمل من خلال بدء الخوارزمية الهجينة مع مجموعة من النملات ترتحل في فضاء البحث من المصدر الى الهدف. ثم تطبيق تقنية البحث الفوضوي على النملات لاختيار اي من النملات مجدية او غير مجدية وصولا الى امثلية البحث. النموذج لمقترح اطلق عليه اسم (H-T-S-C). في كل دورة من دورات نظام مستعمرة النمل يتم تطبيق البحث الفوضي لاستخراج جدوى كل نملة وترتيبها تصاعديا حسب جدواها. النملات التي في البداية (ذات الجدوى العالية) سوف يتم تحديثها بواسطة نظام مستعمرات النمل بينما النملات التي في النهاية (ذات الجدوى المتدنية) سوف يتم تحديثها بواسطة البحث الفوضوي. في هذا البحث تم استخدام البحث الفوضوي ليش فقط لتحسين النملات ولكن لتحسين تشتت مجمعات النمل وذلك لتجنب وقوع خوارزمية نظام مستعمرة النمل الامثلية المحلية. النتائج بينت ان الخوارزمية الهجينة المقترحة قد حسنت نسبة استلام الرسائل بمايقارب 10% وقللت من التأخير بين حزمة وحزمة بما يقارب 10% وقللت الاختناقات بما يقارب 5% وقللت من الوقت المستغرق للوصول من المصدر الى الهدف بمايقارب 3% .

الكلمات المفتاحية:البحث الفوضوي و نظام مستعمرة النمل و الخوارزمية الهجينة و خوارزمية التوجيه الشبكي.

1. Introduction

The basic idea behind ACS algorithms for network routing is the acquisition of routing information through the sampling of paths using small control packets, which are called ants. The ants are generated concurrently and independently at the nodes, with the task to test a path from a source node s to an assigned destination node d. The ant collects information about the quality of its path (e.g. end-to-end delay, number of hops, etc.), and uses this on its way back from d to s to update the routing information at the intermediate nodes and at s [1].

In [2] Cauvery N. K. et al., propose ACS algorithm to explore the network using intelligent packets. The paths generated by ants are given as input to genetic algorithm. The genetic algorithm finds the set of optimal routes. The importance of using ACS algorithm is to reduce the size of routing table. The significance of genetic algorithm is based on the principle of evolution of routes rather than storing the precomputed routes. In [3] Nofal M. et al., proposed to evaluate the performance of the AntNet routing algorithm in terms of efficiency and security in peer-to-peer networks. Using the network simulator NS2, a simulator is implemented for a network of 8-nodes which simulates the ant colony intelligence in deciding the most efficient and secured path from source to destination nodes. In [4] Roy B. et al., introduce one of the major issues of routing to the mobility of the nodes. The biggest challenge in this kind of networks is to find a path between the communication end points satisfying user's QoS requirement. The proposed algorithm combines the idea of Ant Colony Optimization (ACO) with Optimized Link State Routing (OLSR) protocol to identify multiple stable paths between source and destination nodes.

In [5] Soltani A. et al., a new type of ant (helping ants) proposed to the AntNet algorithm. The resulting algorithm, the ‘‘modified AntNet,’’ is then simulated via NS2 on NSF network topology. The network performance is evaluated under various node-failure and node added conditions. Statistical analysis of results confirms that the new method can significantly reduce the average packet delivery time and rate of convergence to the optimal route when compared with standard AntNet. In [6] Dhillon S. et al., compare the performance of AntNet with Dijkstra's shortest path algorithm. Simulations show that the performance of AntNet is comparable to Dijkstra's shortest path algorithm. Moreover, under varying traffic loads, AntNet was the best. In [7] Yoshikawa M. et al., propose a new hybrid routing algorithm which combines Tabu search with Ant Colony Optimization. The proposed hybrid technique enables to find the shortest route including the blind alley. Experiments prove the effectiveness in comparison with conventional routing algorithm such as Dijkstra algorithm.

Chaos is a kind of non periodic movement style. It exists widely in the nonlinear system and is unique to the system. It appears stochastic but can be generated through deterministic means. Chaos is a kind of unshaped out-of-order state, which blends with specific forms relative to some ‘‘immobile points’’, ‘‘periodic points’’. Chaos has subtle internal structure and it is a kind of ‘‘strange attractor’’, which can attract the movement of system and confine it within the specified range [8].

This paper introduce proposed hybrid ACS-CS algorithm which injects CS into ACS to direct the search to feasible area of search space by applying proposed feasibility model (H-T-S-C) to conduct the feasible ants from infeasible one after each iteration in ACS by CS.

2. Mathematical Formulation

The chaos searching (CS) is a new kind of searching method. The basic idea of the algorithm is to transform the variable of problems from the solution space to chaos space and then perform search to find out the solution by virtue of the randomcity, orderliness and periodicity of the chaos variable [9]. Chaos searching technique includes two steps :firstly, search all the points in turn within the changing range of variables and taking the better point as the current optimum point; then regard the current optimum point as the center, a tiny chaos disturbance is imposed and more careful search is performed to find out the optimum point. The chaos search technique has many advantages such as; it is sensitive to the initial value, easy to skip out of the locally minimum value, fast searching speed and global gradual convergence. The following Logistic map is used to generate the chaos sequence because it is more convenient to use [8, 9]:

$$Z_{i+1} = \mu Z_i (1-Z_i) \quad \ldots\ldots \quad (1)$$

where $Z_i \in [0,1]$ (i=1, 2, ……) is the chaos variable, i (i=1,2,….) is the times of iteration; and μ is the control parameter. It is easy to testify that the system is entirely in chaos situation when $\mu = 4$ and the chaos space belong to zero and one [8].

ACS differs from the previous ant system because of three main aspects: The state transition rule provide a direct way to balance between exploration of new edges and exploitation of a priori and accumulated knowledge about the problem [10],

$$S=\begin{cases} \arg\max_{u\epsilon J_{k(r)}} \{[\tau(i,j)].[\eta(i,j)]^{\beta}\} & if\ q \le q_0\ \ (exploitation) \\ \\ S & otherwise\ \ \ \ (biased\ exploration) \end{cases} \quad (2)$$

where τ(i, j) is the pheromone trail of edge (i, j), the heuristic desirability η(i, j) = $1/d_{ij}$ is the inverse of the length from node i to node j (η(i,j)), s_k (i) is the set of nodes that remain to be visited by ant k positioned on node i (to make the solution feasible). Also, β is a parameter which determines the relative importance of pheromone versus distance (β >0), q_0 is a random number uniformly distributed in [0, 1], and q_0 is a parameter (0≤ q_0 ≤1) which determines the relative importance of exploitation versus exploration. In addition, S is a random variable which gives the probability with which ant k in node i chooses to move to node j that is selected according to the probability distribution. Eq. (3) below, which present the probability with which ant k currently at node i, chooses to go to node j [1,2].

$$\rho^k(i,j) = \frac{[\tau(i,j)[\eta(i,j)]]^{\beta}}{\sum_{i\epsilon n^k}[\tau(l,j)[\eta(l,j)]]^{\beta}} \quad (3)$$

Where n_i^k is the feasible neighborhood of ant κ when being at node i, that is, the set of nodes that ant k has not visited yet. The state transition rules resulting from both of Eqs. (2) and (3) is called *pseudo-random-proportional rule.* This state transition rule, as with the previous random-proportional rule, favors transitions towards nodes connected by short edges and with a large amount of pheromone. In ACS only the globally best ant (i.e., the ant which constructed the shortest tour from the beginning of the trial) is allowed to deposit pheromone. This choice, together with the use of the pseudo-random-proportional rule, is intended to make the search more directed: Ants search in a neighborhood of the best tour found up to the current iteration of the algorithm. Global updating is performed after all ants have completed their tours. The pheromone level is updated by applying the global updating rule of Eq. (4) [10].

$$\tau(i,j) \leftarrow (1-a)\cdot\tau(i,j) + a\cdot\Delta\tau(i,j) \quad (4)$$

$$\text{Where}\begin{cases} (L_{gb})^{-1} & if\ (i,j) \in global-best-tour \\ \\ 0 & otherwise \end{cases}$$

Where, 0<α<1 is the pheromone decay parameter, and L_{gb} is the length of the globally best tour from the beginning of the trial. As was the case in ant system, global updating is intended to provide a greater amount of pheromone to shorter tours. Eq. (4) dictates that only those edges belonging to the globally best tour will receive reinforcement. We also tested another type of global updating rule, called *iteration-best*, as opposed to the above called *global-best*, which instead used L_{ib} (the length of the best tour in the current iteration of the trial), in Eq. (4). While ants construct a solution a local pheromone updating rule (local updating rule, for short) is applied. While building a solution (i.e., a tour) of the network routing, ants visit edges and change their pheromone level by applying the local updating rule of Eq. (5) [4].

$$\tau(i,j) \leftarrow (1-\rho)\cdot\tau(i,j) + \rho\cdot\Delta\tau(i,j) \quad (5)$$

Here , $0< \rho<1$ is the local pheromone decay parameter. The effect of local-updating is to make the desirability of edges change dynamically. Every time an ant uses an edge, it becomes slightly less desirable because it loses some of its pheromone making them less desirable for future ants and allowing for the search of new, possibly better tours in the neighborhood of the previous best tour [5].

3. Problem Definition and Proposed Objective Function

From the above section can conclude the following general view about the ACS and especially AntNet: After each of iteration in ACS there is a local update and global update. Where local update modifies pheromone on edges and global update when all ants have terminated their path, the amount of pheromone on edges is modified again. After each of iteration in ACS, the Time to life (TTL) of ant is consumed. So there are ants may die after near time. After each of iteration in ACS there is congestion (overload) on some nodes, come from selecting many of the ants of this node. After each of iteration in ACS there is a next iteration (unless final iteration) in each iteration the same rules and updates are done (deterministic), this cause the stagnation problem which means the routing tables are freeze and there is no new solution although in reality there are many of best solutions. After each iteration there is a need to shake the ACS to enhance its results by evaluate the ants to support ants with high priority to continue (these ants will update their pheromones with ACS transition rules) and trying to enhance the ants with low priority (these ants will update their pheromones with CS). The evaluation of ants done according proposed feasibility model (H-T-S-C) which consists of four parameters, according their priority, these are:

Pheromone rate (H) on last edges visited by ant, the pheromone value will be customized as three intervals (high, medium and low), to consider ant feasible its last pheromone must be high or at least medium. This parameters will be given 30% of feasibility (high= 30%, medium= 20% and low= 10%). TTL of ant (T), the TTL value will be customized as three intervals (high, medium and low). To consider ant feasible its TTL must be high or at least medium. This parameter will be given 30% of feasibility (high= 30%, medium= 20% and low= 10%). Routing table stagnation state (S), of nodes related to the ant, the stagnation value will be customized as three intervals (high, medium and low), to consider ant feasible its stagnation must be low or at least medium. This parameter will be given 30% of feasibility (high= 10%, medium= 20% and low= 30%). Congestion state (C), is the number of shared nodes selected by the ant and many other ants, the congestion value will customized as three intervals (high, medium and low), to consider ant feasible its congestion state must be low or at least medium. This parameter will be given 10% of feasibility (high= 3%, medium= 6% and low= 10%). The objective function is the proposed feasibility model (H-T-S-C) which is calculated by equation (6).

$$\text{Feasibility (H-T-S-C)} = H+T+S+C \qquad (6)$$

4. The Proposal of Hybrid ACS and CS

The main idea of hybrid algorithm is to inject ACS with CS to enhance ACS-based network routing algorithms. In order to combine their advantages and to avoid their disadvantages. Before explaining the proposed algorithm in details, figure (1) explains the basic modifications applied on ACS to present it as hybrid ACS-CS.

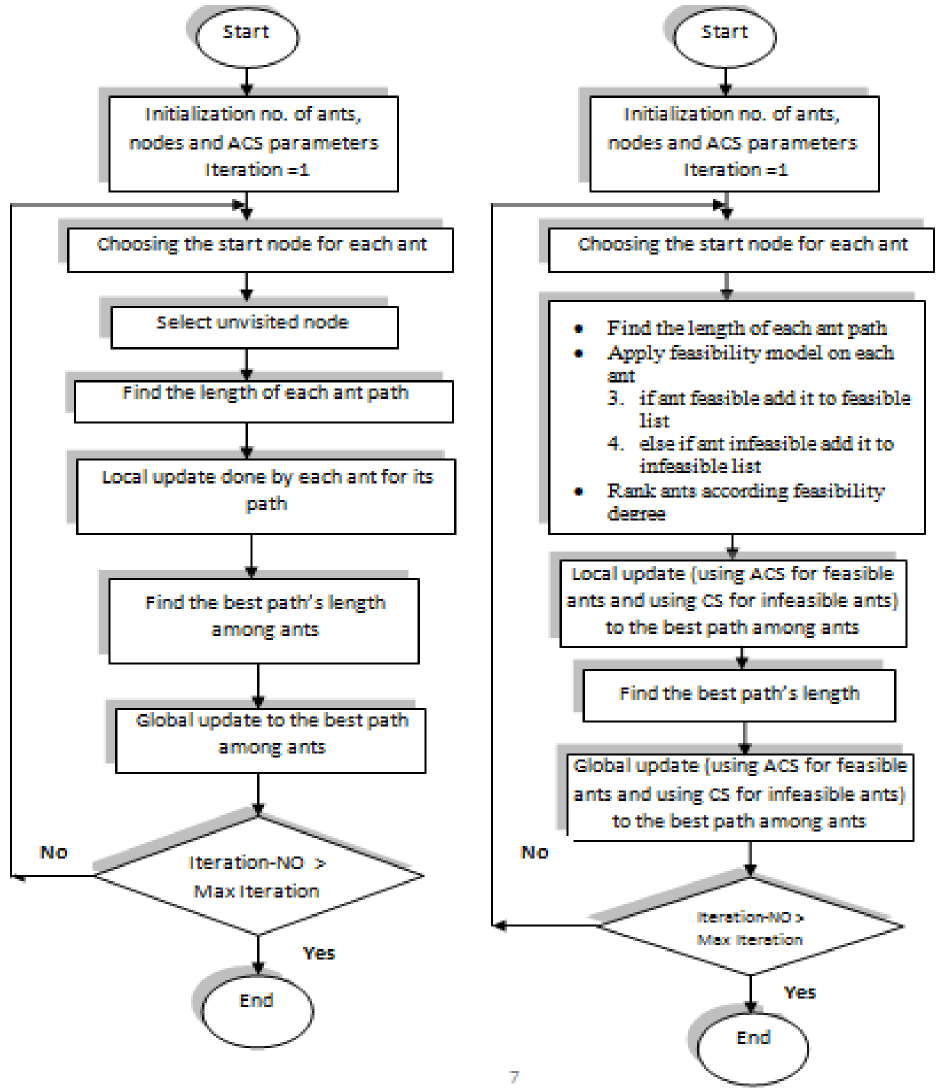

Figure (1): Left; Traditional ACS. Right; Proposed ACS

The algorithm can be described in general in the following two points:

1. The ants of the swarm are randomly initialized. Then, proposed modest model aim to exam the ants to judge whether the ants is feasible or not, not just detect the feasibility but also labeled the ant with its feasibility degree. Then if the ant is feasible add it to the feasible list; otherwise, if the ant is infeasible add it to the infeasible list and labeled the ant with it is infeasibility degree.
2. The ants in the feasible list are ranked in ascending order (according to feasibility degree); after that, the ants in the infeasible list are ranked in ascending order (according infeasibility degree). Then, the pheromone of ant's are updated according to ACS rules; and the ants in infeasible list are updated by use of CS. After iteration, the fitness values of the ants are computed again. The above steps are repeated until the termination criterions are met. The steps of the proposed algorithm are listed in details as follows in algorithm (1).

Algorithm (1): Hybrid ACS-CS
ACS-CS Input: input MA Max no. of Ants, input MI Max Iterations to determine the maximum iterations needed for implementation and input MN Max no. of nodes, which present the network structure. ***ACS-CS Output:*** List best path made through MI by ants passing through nodes. ***ACS-CS Constraints:*** Identify the starting node for each ant to complete its tour through nodes such that each node can be visited once only. Unduplicated starting nodes in order to improve performance of ant route. ***ACS-CS Initialization:*** Initialize parameters are used in transition rule and determine initial pheromone trail for each node should acquire. MI which determines the maximum iterations needed for implementation, initialize MI = 1 up to 30. MA which determines the maximum ants needed for implementation, initialize MA = 7 (could be less or more). MN which determines the maximum nodes present network structure for implementation, initialize MN = 20 (could be less or more). ***ACS-CS Process*** 1. After Initialize the parameters above begin with iteration I=1. 2. Initialize the ith (i = 1, 2, . . . , M) ants randomly with initial pheromone. 3. Select random starting node for each ant. 4. Through the iteration do the following; • Loop all ants to build their paths through nodes; all nodes must be visited one time. • Compute the feasibility of the ants using the proposed ant feasibility model (H-T-S-C) by use of CS. So M ants will divide into feasible ants m and infeasible ants n. • If ant is feasible add it to the feasible list with its feasibility degree; otherwise, the ant is infeasible, add it to the infeasible list also with its infeasibility degree. • Rank the ants according to feasibility degree. The ants in both lists feasible and infeasible ranked in ascending order. • Update the local best four parameters (H-T-S-C)i and global best parameters (H-T-S-C)g. For the ith (i = 1,2, . . . ,M) ants, compare ant's feasibility with its best (H-T-S-C)i. If current value is better than best (H-T-S-C)i, then set the current value to best (H-T-S-C)i. Compare the first ant's (H-T-S-C) with the global best (H-T-S-C)g. If current value is better than best (H-T-S-C)g, then set the current value to best (H-T-S-C)g . • Update m ants with ACS and update n ants with CS. • Termination conditions. I=I+1, If the number of iterations is larger than the maximum number of iterations (MI), go to Step 5,otherwise go to Step4. 5. Output the results. Output the optimal ant, compute and output the upper level and lower levels of (H-T-S-C) values. **End**

5. Experimental works and Results

This section tends to explain the implementation of the proposed algorithm which aims to enhance ACS algorithm using hybrid ACS-CS. The proposed algorithm will be applied on ACS-based network routing algorithms (ANTNET). The proof of validation done through implementing (ANTNET) as pure ACS then implementing (ANTNET) as hybrid ACS on the same simulation environment from all parameters: no. of iterations, no. of nodes and no. of ants. Through the implementation of algorithm, the following issues are considered:

No. of ants must be increased with increasing no. of nodes for more efficient implementation. No. of iteration equal to 30 iteration could fix the stagnation problem and gives a good view about congestion state. Represent packets and messages as bits to calculate the two measures (MDR and jitter). Represent the queue of congestions state for each node as number of ants visits it concurrently to calculate the congestion state of each node. The pheromone values are decreased in regular time intervals of $\tau = 1$ second. The pheromone increasing rate value is $\varphi = 0.1$.

In Experimental works, as mentioned above there are four structures of Network taken in account. These structures are: network structure of five nodes, network structure of ten nodes, network structure of fifteen nodes and network structure of twenty nodes. For all these four structures concentration has been on two dimensions in problems of routing algorithms these are congestion and stagnation. Both could be measured by the following four measures:

- Message Delivery Ratio (MDR): Message Delivery Ratio is defined as the ratio between the number of messages sent by sources and number of messages received by destination. For example if the sent messages were 10 and received messages 8, so MDR will be 80%.
- Average End-to-End Delay (jitter): Time taken for the packets to reach the destination. For example the expected time of packet reaching is 1ms but the packets reaching through 1.3ms, so jitter will be 0.3ms.
- Congestion State: The queue of nodes to reach the destination. It is concentrating on delay caused by congestion.
- Time of search: the time consumed in search the space of paths to find the best paths. For example the expected time to find best paths is 10ms using traditional ACS but the time to find best paths is 7ms using proposed ACS-CS.

To get a better idea of the performance of ACS-CS, the traditional ACS will be compared through traditional (ANTNET) with the proposed hybrid ACS-CS through hybrid (ANTNET). Figures (2 and 3) explain the results of comparisons. From figure (2 and 3), the proposed ACS-CS is better than the traditional ACS through the four most important criteria to measure network routing performance.

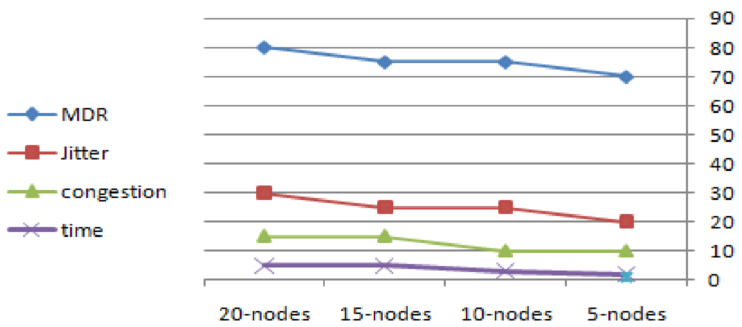

Figure (2) ANTNET results with traditional ACS

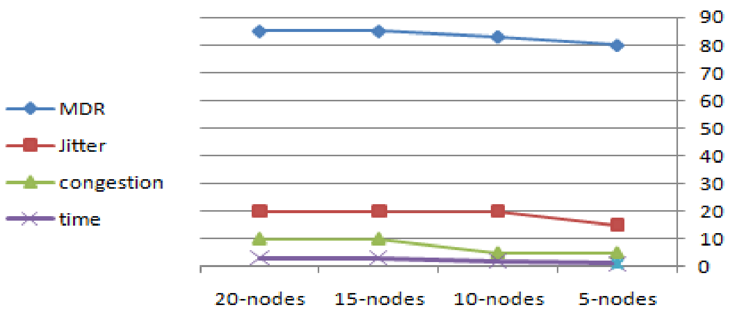

Figure (3) ANTNET results with proposed ACS-CS

6. Conclusions

This research present a new (ACS-CS) for ACS-based network routing through experimental works, the following points can be concluded:

1. The proposal of using CS aid to direct ACS toward feasible parts of search space by determining the feasible and infeasible ants after each iteration.

2. Local and global updating of ants with two techniques these are updating by ACS for feasible ants and updating by CS for infeasible ants; support ACS with shake to the search space this will help to avoid the stagnation.
3. CS is not only used to enhance routing performance but also embedded in the ACS to improve the worse ants. This way not only enhances the ants but also improves the diversity of the ants warm to avoid ACS trapping in the local optima.
4. The feasible weighting value is introduced to replace the fitness value of the ants when it is infeasible, which can force the infeasible ant to be feasible. In the early stage of the algorithm, the feasible weighting value is used to rank the infeasible ants, which can avoid the situation that the infeasible ants is denoted as the best ant although it is the best of all when only the fitness value is used by all ants.
5. The proposed ACS-CS improves the performance of ACS-based network routing algorithms (ANTNET) in four scenarios (message delivery ratio, jitter, congestion state and time).

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