Intellectual Behavior of a Group of Wild Animals: A Computational Intelligence Study

Avtar Singh Buttar, Ashok Kumar Goel, Shakti Kumar

Abstract— ***Numerous methodologies have been invented inspired by nature and based on real life behavior of species which perform task in a group. In this paper, a novel methodology based on intelligent chasing and hunting methods adopted by the animals in a group to chase & hunt their prey is presented. The dog is taken as prime model for developing the methodology. The method is named as "Dog Group Wild Chase & Hunt Drive (DGCHD) [18]. The algorithm is implemented on Traveling Salesman benchmark problem available in literature. The problem has been solved by different researchers for testing their proposed novel intelligent algorithms in various nature inspired technologies such as Ant Colony System, Genetic Algorithms etc. The results obtained are very optimistic and encouraging.***

Index Terms— ***Dogs behavior, Chasing & hunting, Computational Intelligence, Dog Group Wild Chase & Hunt Drive (DGCHD), combinatorial optimization.***

I. INTRODUCTION

Many nature inspired algorithms / meta-heuristics have been developed. Ant Colony optimization (ANTS algorithms), is inspired by the behavior of real ants. Tabu Search (TS) relies on the systematic use of memory to guide the search process. Evolutionary Computation techniques use design principles inspired from models of the natural evolution of species: evolution strategies, evolutionary programming and genetic algorithms are population-based algorithms that use operators inspired by population genetics to explore the search space. Simulated Annealing is inspired by an analogy between the physical annealing of solids. In the late 1940s, Donald Hebb made one of the first hypotheses of learning with a mechanism of neural plasticity called Hebbian learning. Particle Swarm optimization (PSO) was based on the swarm behavior of such as fish and bird schooling in nature. Honey Bee algorithm mimics the behavior of honeybee. The multi-agent optimization system (MAOS) is a nature-inspired method, which addresses the self-organization of agents working with limited declarative knowledge and simple procedural knowledge under ecological rationality. Specifically, agents explore in parallel based on socially biased individual learning (SBIL) and indirectly interact with other agents through sharing public information organized in the environment (ENV*)*. These algorithms have been applied for solving TSP instances. Since TSP is NP-Complete, Moreover, TSP has various applications, such as very large scale integration (VLSI) design, rearrangement clustering, predicting protein functions, printed-circuit-boards manufacturing, data transmission in computer networks, power-distribution networks, image processing, pattern recognition, robot navigation, and data partitioning.

In this paper, the methodology based on the intelligent behavior of dog's group is illustrated and tested on benchmark TSP problem to check its efficiency. The remainder of the paper is organized as follows: Section II gives a brief description of Dog's and their behavior while Section III describes development of DGCHD methodology and the algorithm based on chasing & hunting methodology adopted by dogs. Section IV outlines development of DGCHD algorithm for travelling salesman problem (TSP) and the implementation of algorithm for solving TSP benchmark problem. Section V outlines computational intelligent study and experiments undertaken and the effectiveness of the algorithm is evaluated, the results obtained and plotted. Finally, the conclusions and future directions are outlined in Section VI.

II. DOG'S AND THEIR BEHAVIOR

A dog is very active, loyal and sensible animal. Its behavior at different moments is very loyal to his master and may bark loudly and watch to see any odd entry to his master's house. There are five main sensing organs gifted to dogs as human being nose for capable to smell, ears for hearing, eyes to see, touch feelings on skin and bark loudly all around. However, some are more highly developed, and others are deficient compared with those of humans. It can observe each and every moment in his master's home. Dogs can detect drugs, explosives, and the scents of their masters [1]-[4].

A. Anatomy of dog's nose

Olfaction, the act or process of smelling, is a dog's primary special sense. A dog's nose consists of a pair of nostrils (nares) for inhaling air and odors and a nasal cavity. The olfactory receptor cells in a its nose extend throughout the entire layer of specialized olfactory epithelium found on the ethmo-turbinate bones of the nasal cavity. The olfactory portion of the nasal mucous membrane contains a rich supply of olfactory nerves that ultimately connect with the highly developed olfactory lobe in its brain. Dogs possess an additional olfactory chamber called the vomeronasal organ that also contains olfactory epithelium. The vomeronasal organ, known as Jacobson's organ, consists of a pair of elongated, fluid-filled sacs that open into either the mouth or the nose. It is located above the roof of the mouth and behind the upper incisors. Interestingly, the olfactory receptors in the nasal cavity are anatomically distinct from those in the vomeronasal organ.

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Each receptor neuron (nerve cell) in the olfactory epithelium of the nasal cavity has a dendrite that ends in a knob with several thin cilia covered by mucus. Receptor neurons in the vomeronasal organ typically lack cilia but have microvillus on the cell surface [9]-[11].

Dog's sense of smell is by far the most acute and is immeasurably better than that of humans [1]. It has been estimated that its sense of smell is 100,000 times more powerful than a human. Scientists think that humans have about 40 million olfactory receptors, versus 2 billion for a dog [2]. Dogs have about 25 times more olfactory (smell) receptors than humans do. These receptors occur in special sniffing cells deep in its snout and are what allow it to "out-smell" humans. Dogs can sense odors at concentrations nearly 100 million times lower than humans. They can detect one drop of blood in five quarts of water. Dogs are used for such tasks as tracking missing persons, digging underground, and tracing toxic substances, such as gases, that are undetectable by humans. Dogs can detect drugs, explosives, and the scent of their masters.

By comparison dogs have scent cells spread all over a large area and have an estimated 125-220 million scent cells depending on the size of the dog. They can use each nostril independently and are good at distinguishing one odor from another and remembering it [8].

B. Anatomy of dog’s ear

A dog's ear has three major parts: an inner, middle and outer ear. The outer ear is the ear flap, also known as the pinna. This pinna is shaped differently according to the breed of dog. The pinna funnels sound into the ear canal. The ear canal is long and almost makes a right angle as it funnels into the ear. The middle ear has a tympanic membrane or ear drum. It is fragile and can be damaged by disease or cleaning. The middle ear has three small bones, an air cavity called the bulla and a eustachian tube. The inner ear contains nerves for hearing and the center for balance [14]. Dogs have tiny hairs in their ear canals. These help them detect changes in position that may help them to hear sounds better. This is why a dog cocks its head to one side occasionally in order to hear a sound better or more clearly. Dogs can hear from 40 Hz to 60,000 Hz in range. This is similar to humans in the lower range but much higher at the high end. Dogs can hear high-pitched whistles and small animal prey. Dogs can also distinguish between sounds that seem identical to a human, such as hearing the difference in a family member's footsteps as opposed to those of a stranger. Dogs' ears can move independently from each other, which give them greater capability to determine direction and cause of sound. Dogs are able to register sounds of 35,000 vibrations per second (compared with 20,000 per second in humans), and they also can shut off their inner ear in order to filter out distracting sounds. Dogs can hear at four times the distance humans can – that means you might hear something from a 100 yards away while a dog could hear from a quarter of a mile away. Their ears are also better designed to gather more of the available sound wave. They have 15 different muscles that move their ears in all directions, plus they can move one ear at a time – and independently of the other to absorb even more information [1], that helps them to rapidly pinpoint the exact location of a sound. Eighteen or more muscles can tilt, rotate and raise or lower a dog's ear. Additionally, a dog can identify a sound's location much faster than a human can. So, they possess an acute sense of hearing.

C. Behavior of Dogs in Group

Dogs form small groups, each group consisting of some senior members and some junior members. They follow the command and path as per the senior members. During searching of food, their attack is very systematic. The group consists of chasers and hunters. Barking, hearing & wider vision capabilities are very important tools for dog to collect the information all around. The main sense used by chasers is smell and moving on the path following direction of maximum smell intensity for chasing and barking loudly to communicate with each other to follow them. They also use smell to decode scent messages left by other animals, friend or foe, predator or prey [9]. A wild canine's sense of smell is especially important in habitats where seeing prey is difficult such as the thick underbrush of forests.

The chasers enter in the field, due to presence of grass etc. may not be visible to the hunter. They are moving on all possible ways, sensing the intensity of smell along the path to follow and chase their prey. During chasing, prey may run away. The prey’s position may be static (in sleeping state) or dynamic (moving). Chasers bark continuously during searching process. Hunters shift their position as per their barking level, movement and judge and move around the hunting field. Hunters can run as faster as food-targets to catch/kill them. Thus, they have divided their jobs as per their physical capabilities.

D. General behavior of preys

Most of the prey lives in holes as their nests. Prey move for search of food from their holes. In day to day life, prey search for food and meet each other via link paths and mark the area/path by laying their urine. When predators arrive, they move randomly on common paths and run for survival. From the ancient times, human being are exploiting the same intelligence of dogs for chasing & hunting the small animals like hares, rabbits, pigs, foxes, jungle cats etc for their meal.

E. Artificial Hunting field

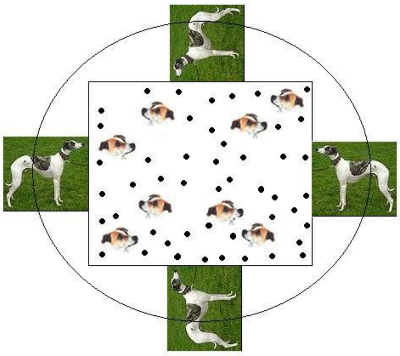

Fig. I Artificial Hunting field

As shown in Fig. I, artificial chasers dogs are agents which move from in the field to search food target from the different sides at random. They chase the prey taking smell and barking level of each other into consideration. They follow the path accordingly to locate the target. The hunter stands along with his master. The hunter watches the situation by tracing the area /path along the chasers are their barking level. The hunter catches the prey and delivers to his master.

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This process continues until all the preys are hunted or prey runs away for survival.

III. DEVELOPMENT OF DGCHD METODOLOGY

Original concept of Artificial Dogs developed as follows:

A. Artificial Chaser Dogs

The movement of the chaser dog from one node to next node proceeds on graph according to probabilistic function comprising of smell, health of prey and barking level of chaser dogs.

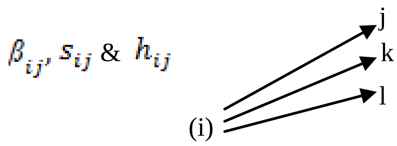

Fig. II Movement of chaser dog

The dog selects next node according to the probabilistic function (1)

$$\underset{k}{p}(i,j)=\left\{\frac{[ß_{ij}]^{\alpha}.[s_{ij}]^{\beta}.[h_{ij}]^{\gamma}}{\sum_{1}^{m}[ß_{ij}]^{\alpha}.[s_{ij}]^{\beta}.[\varkappa_{ij}]^{\gamma}}\right\} \quad (1)$$

where

S------Initial smell of prey
H-----initial health of prey
s_{ij}---- Smell level of prey/food target in the direction of i and j
$ß_{ij}$--- Barking level of prey/food target in the direction of i and j
h_{ij} --Health of prey with initial health 100%
nc— Total no. of chasers
nh---- Total no. of hunters
α-----weigh of Barking level
β----- weigh of Smell level
γ----- weigh of Health level
ϕ----% of barking level reduced
λ------ratio of optimal near solution of heuristics/constant and minimum value

When chaser runs after prey, the prey tries to escape. This period depends on the time for which prey is chased. The health of prey decreases in the process as it feels exhausted.

The health of prey is thus, updated as:

$$h_{ij}=h_{ij}\text{-}rd\ (i,j) \quad (2)$$

The chaser bark loudly sending message to other members. This barking level also decreases on the way, when moving forward on the path. Other chasers follow that barking and direction on their movement. The barking level is thus, updated as:

$$ß_{ij}=ß_{ij}*\phi \quad (3)$$

For collective decision barking levels in different directions gives the commutative effect given by:

$$ß_{ij}=ß_{ij}+\lambda_{ij} \quad (4)$$

B. Artificial Hunter dogs

Hunter is hunting first the direction or the path along maximum barking level, movement of chasers. Hunters prepare themselves to attack the prey along the selected path whose health is the minimum and can be easily killed. The hunter Dog selects prey from the hunting choice array according to equation (5)

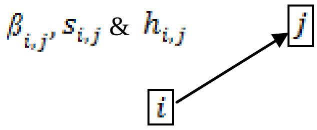

Fig. III Movement of hunter dog

$$\eta(i,j)=\left(\frac{ß(i,j).(H-h((i,j))}{max\{\sum_{i=1}^{i=m}(ß(i,j).(H-(h(i,j)))\}}\right) \quad (5)$$

The hunter selects prey from hunting choice array according to equation (6) giving Hunting choice matrix *ht*

$$ht\,(i,j)=\begin{cases}1, & if\ \eta>\eta_0\\ 0, & if\ \eta<\eta_0\end{cases} \quad (6)$$

1…represents hunted prey path
0…otherwise
η_0--- hunting threshold decision value between (0, 1)

C. DGCHD methodology

```
Initialize the data
Link matrix; adjacent matrix to link all nodes;
Co-ordinate matrix; geometric co-ordinates of all nodes;
Distance matrix; distance between all nodes
Smell matrix; smell of all prey in different directions
Health matrix; Health of all prey in different directions
Barking matrix; Initial level of barking in different directions
Hunter choice matrix; Initialize matrix
Place the chasers at the origin node.
Select the nature/group of food target
Initialize the chasing from a randomly selected node i
Move chasers as per smell of food target, barking level &
health level consideration on selected path ;from i to j
Record the barking level, smell of target and health level
during each movement; between i & j
Update the barking level and health level
Start hunters to hunt with the sense of maximum barking
level and fall in health level at each visited node
Catch the food target with hunter
Bring and Place the target
Return
End
```

Fig. IV Pseudo-Code for DGCHD Methodology

IV. DEVELOPMENT OF DGCHD ALGORITHM FOR TRAVELLING SALESMAN PROBLEM (TSP)

The Travelling Salesman Problem (TSP) is a problem in combinatorial optimization studied in operations research and theoretical computer science. Given a list of cities and their pair-wise distances, the task is to find a shortest possible tour that visits each city exactly once. The problem was first formulated as a mathematical problem in 1930 and is one of the most intensively studied problems in optimization. It is used as a benchmark for many optimization methods. The problem is computationally difficult, and no general method of solution is known, and the problem is NP-hard.

The Traveling Salesman Problem is one of the most intensively studied problems in computational mathematics. A salesman must visit n cities, passing through each city only once, beginning from one of them which are considered as his base, and returning to it. The distance between each city (whichever combination possible) is given. The program of the journey is required, that is the order of visiting the cities in such a way that the cumulative distance is the minimum. The TSP can be presented by a complete weighted graph G= (N, A) with N being the set of nodes representing the cities and A being the set of arcs representing the paths. Thus, an optimal solution to the TSP is a permutation π of the node indices {1, 2…n) such that the length $f(\pi)$ is minimum, where $f(\pi)$ is given by

$$f(\pi)=\sum_{i=1}^{n-1} d_{\pi(i)\pi(i+1)} + d_{\pi(n)\pi(1)} \quad (7)$$

The proposed algorithm for minimum distance path is described as follows:

procedure DGWCHD ( )
begin
/ initialization */*
get-a- instance (xy);
$d_{ij} := \sqrt{(y_j - y_i)^2 + (x_j - x_i)^2}$;
po := node/prey degree-ordering for- prey list ( ) ;
d_{min} := find minimum distance for- prey list (po);
*/*starting first LOOP, i.e.iteration */*
while (all preys are chased and hunted or terminating condition reached)
/ Phase 1: chasing search by chasers to find po */*
/ select first prey i present on randomly selected node i */*
/ put i in po */*
Loop /* at this level each loop is called a step */
select a prey pi from node ni i := 1, n;
/ using probabilistic function*/*
select next prey pj from node nj j = 1, n-1;

$$\max_{j=1,n}[pk\ (i,j)\ ]=\left\{\frac{[b_{ij}]^{\alpha}.[s_{ij}]^{\beta}.[h_{ij}]^{\gamma}}{\sum_{j=1}^{n}[b_{ij}]^{\alpha}.[s_{ij}]^{\beta}.[h_{ij}]^{\gamma}}\right\} \quad \text{for } i\neq j$$

= 0 for i = j
/ updates */*
$h_{ij}=h_{ij} - d_{ij}$;
$h_{ji}=h_{ij}$;
$b_{ij}=b_{ij}* \phi$;
$b_{ji}=b_{ij}$;
/* put j in po */
end;
find prey order po with d_{min} ;

ftr=10*optimal/ d_{min} ;
/*comprehensive update for health for efficient po */
for
$h_{ij}=h_{ij} - d_{ij}$; i= pi,j= pj;
$h_{ji}=h_{ij}$;
end ;
$\lambda =$ftr/100;
*/*comprehensive update for barking for efficient po */*
for
$b_{ij}=b_{ij} + \lambda$; ;
end
/ Phase 2: hunting by hunters */*
begin
for

$$\eta(i,j)=\left(\frac{b(i,j).(H-h(i,j))}{max\{\sum_{i=1}^{i=n}(b(i,j).(H-h(i,j))\}}\right); \text{ i= pi, j= pj;}$$

end;
/ prepare hunting array */*
begin

$$ht(i,j) = \begin{cases} 1, & if\ \eta(i,j) > \eta_0 \\ 0, & if\ \eta(i,j) < \eta_0 \end{cases}$$

*/*end of while */;*
end;
*/*outcomes as efficient po, $d_{min.}$, and plot optimal path */*
po;
$d_{min;}$
plot (po,xy)

Initially, m artificial dogs are placed at randomly selected cities. At each time step they move to new cities and modify health level and barking level on the edges used –this is local updating. When all the dogs have completed a tour the dog that makes the shortest tour modifies the edges belonging to its tour –termed global updating– by adding an amount of barking that is inversely proportional to the tour length. The barking level decreases in each movement as per eqn. (3), health level decreases in each movement as per eqn. (2) if the probability is same, then smallest numbered city is selected. For global updating function (4) is used.

The different parameters values are taken as follows: N=Total no. of cities, α=(*.1,-0.2)*, β=5, γ =1, $ß_{ij}$=.0001, λ=optimal/best solution found, η=(0.95-1), ϕ=(0.7-0.9), nearest cities=5, S=100, H=100, nc=50, nh=100, [xy] is the co-ordinate matrix consisting of geometric co-ordinates of all nodes. To calculate λ, numerator is taken as the best result found or optimum result is taken from literature and denominator as current best result obtained by each chasing step. The downfall in health level indicates information regarding decrease in prey health at each chaser step. The barking level also changes in different steps during runtime. Product of barking level and fall in health level for each hunted step is calculated.

From the results obtained in different evaluations, it is found that the performance of algorithm goes well if parameters vary within above limits.

V. RESULTS AND DISCUSSION

In this work, we have selected the most studied and researched TSP benchmark Burma14 (14 city-problem) taken from TSPLIB95, because most of the other computational techniques are taken from this benchmark problem set bank. The proposed algorithm is implemented on this problem. The tuning of different parameters like health, barking and smell exponents is done to find the optimum solution of this problem. The computational study is carried on a PC with an Intel® Core[TM] i5-560M Processor 2.66 GHz with MATLAB 2012a software. The optimum solution graph is obtained and plotted in Fig. V.

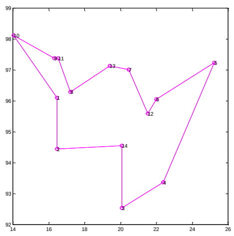

Fig. V Optimum tour graph for TSP problem Burma14

(Real distance =30.8785, integer tour length=30)

The parameters taken and results obtained for different cases (8 in number) are tabulated in Table I. From the results shown in the Table, it is found that the DGWCHD algorithm gives consistently optimum solutions for different sets of parameters, α, β and γ. The different exponent values are taken for different cases. The value of average tour distance for different test cases is obtained between 30.92 and 31.03. It indicates that the quality of solutions found in 100 trials is very close to optimum value, i.e. 30.87. These values are better in comparison with results cited in [29] which vary from 31.18 to 31.82. The consistency of the algorithm to obtain optimum solution is also evaluated and presented in Table I. The minimum value of success rate is 56% and maximum is 88%. The other algorithms implemented on the problem cite the maximum value of success rate as 72% only [29]. The best solution is found for test case 8 as shown in Table I. The time taken for each case is also reported in the Table.

The best solutions are obtained for different trials in each case are plotted in Fig. VI. From the Fig., it is evident that the solutions converge to optimum value in 15 iterations only. The graph shows that in most of the cases optimal value (31.23) is obtained at initial stage itself i.e. in first iterations only. The optimum solution (30.87) is found at different number of iterations with change in value of exponent of smell. Thus, it indicates that the algorithm converges to optimal solution in reasonably small number of iterations.

Table I

Good solutions Consistency of results for Burma14 by proposed algorithm

Test Case	1	2	3	4	5	6	7	8
Number of Chasers	50	50	50	50	50	50	50	50
Iteration	100	100	100	100	100	100	100	100
α	0.118	0.118	0.118	0.118	0.118	0.118	0.118	0.118
β	5	2	3	4	1	6	7	0.5
γ	1	1	1	1	1	1	1	1
Average tour distance	31.0307	31.0167	30.9726	31.0003	30.9332	31.0446	31.1689	30.9206
Average computation time	3.3652	3.0769	3.7094	3.6340	3.2429	2.9380	3.5928	3.8092
Optimum solution obtained/100 trails	56	62	73	65	85	50	42	88

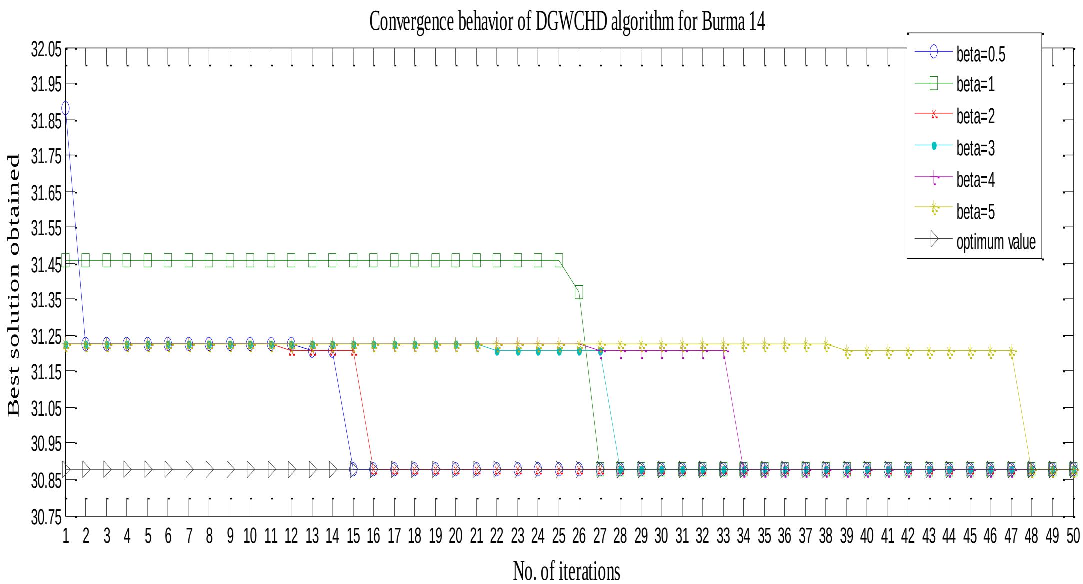

Fig. VI: Convergence Graph for Successful Trials

VI. CONCLUSION

In this paper, DGWCHD a novel methodology is presented to represent the behavior of wild animals, such as dogs as agents. The research work is totally based on chasing and hunting strategies adopted by wild dogs to catch their prey for food. The DGWCHD algorithm is developed as a novel methodology. The proposed algorithm is implemented on TSP Benchmark problem, Burma14. The results obtained are very encouraging and confirm the usefulness of the algorithm for application in related engineering applications.

REFERENCES

1. Natural History museum of Los Angles country
2. Pugs.com "5 Ways Your Dog Senses The World Differently From You"
3. WWW.RCMP-GRC.GC.CA ROYAL CANADIAN MOUNTED POLICE "Dog Senses"
4. http://www.aces.edu/counties "The Dog's Sense of Smell"
5. http://www.pet-yard.com/dogs-senses.php
6. http://www.seefido.com/html/dog_s_5_senses_of_dogs.htm
7. http://www.nature.com/nature/journal/v36/n925/abs/036273a0.html
8. http://www.whole-dog-journal.com/issues/7_11/features/ Canine-Sense-of-Smell_15668-1.html
9. http://www.sciencedaily.com/releases/2006/01/060106002944.htm
10. http://jhered.oxfordjournals.org/cgi/content/full/96/7/812
11. www.dog-health-hand-book.com
12. www.dailymail.co.uk
13. http://www.dog-names.org.uk/hunting-dogs.htm "Hunting Dogs"
14. http://ezinearticles.com/?Hunting-Dog-Origins---Tracing-The-Evolution-Of-The- Hunting- Dog & id=1659496
15. http://www.sekj.org/PDF/anzf41/anzf41-545.pdf
16. http://www.ehow.com/how-does_5139011_do-dogs-ears-work.html
17. www.charlottesville-area-real-estate.com
18. A. S. Buttar, A. K. Goel and S. Kumar, Patent Title: Wild Intelligence: A novel intelligence as dog group wild chase & hunt drive (DGCHD), Application No.:DEL/ 1965/2008 Indian Patent Office Journal, issue No.14/2010,pp., 7873 April, 2010
19. F. T Lin, C.Y. Kao, and C. C. Hsu, 1993, Applying the genetic approach to simulated annealing in solving some NP-hard problems. IEEE Transactions on Systems, Man, and Cybernetics, 23,1752–1767.
20. S. Eilon, C.D.T. Watson-Gandy, and N. Christofides, 1969, Distribution management: mathematical modeling and practical analysis. Operational Research Quarterly, 20, 37–53.
21. M. Dorigo, L. M. Gambardella, Ant Colony System: A Cooperative Learning Approach to the Traveling Salesman Problem , IEEE Transactions on Evolutionary Computation Vol. 1,No. 1,Pp. 53-66, 1997
22. F.A.N. Huilian "Discrete Particle Swarm Optimization for TSP based on Neighborhood" Journal of Computational Information Systems 6:10 (2010) 3407-3414
23. Hui-Dong Jin,Kwong-Sak Leung,Man-Leung Wong, and Zong-Ben Xu An Efficient Self- Organizing Map Designed by Genetic Algorithms for the Traveling Salesman Problem IEEE Transactions on Systems, Man, and Cybernetics—Part B: Cybernetics, Vol. 33, No. 6, December 2003 877
24. Wei-Neng Chen, Jun Zhang, Henry S. H. Chung,Wen-Liang Zhong, Wei-Gang Wu and Yu-hui Shi, "A Novel Set-Based Particle Swarm Optimization Method for Discrete Optimization Problems" IEEE Transactions on Evolutionary Computation, Vol. 14, No. 2, April 2010
25. M. Albayrak and N. Allahverdi," Development a new mutation operator to solve the Traveling Salesman Problem by aid of Genetic Algorithms" Elsevier, Available online 23 July 2010.
26. Shyi-Ming Chen and Chih-Yao Chien," Parallelized genetic ant colony systems for solving the traveling salesman problem" Elsevier, Available online 23 September 2010
27. Y. Marinakisa, M. Marinaki, "A Hybrid Multi-Swarm Particle Swarm Optimization algorithm for the Probabilistic Traveling Salesman Problem" Computers & Operations Research 37 (2010) 432 – 442
28. Shyi-Ming Chen, Chih-Yao Chien, "Solving the traveling salesman problem based on the genetic simulated annealing ant colony system with particle swarm optimization techniques" Expert Systems with Applications 38 (2011) 14439–14450.
29. Yen-Far Liao, Dun-Han Yau, Chieh-Li Chen, "Evolutionary algorithm to traveling salesman problems", Computers and Mathematics with Applications, Elsevier 2012

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