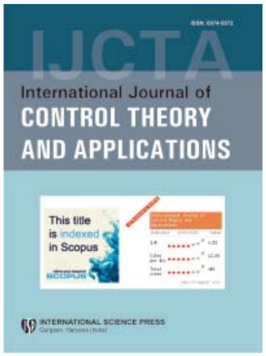

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Adapting to Changing Fitness using Genetic Algorithm

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Abstract : Genetic Algorithm (GA) is a method that has its foundation laid on the "survival of the fittest" theory of Charles Darwin. It uses the principles of Selection, Crossover and Mutation from the science of Genetics. Genetic Algorithms are used in finding solutions to optimization problems in the fields of Computational Science, Bio-informatics, Chemistry, Physics and Engineering. GA is run on a population (of individuals) having one or more parameters that define its fitness. For example, cost is a fitness function in a transportation problem. In this case, the objective is to reduce the total cost of shipping items from factories to warehouses where the production capacity of factories, storage capacity of warehouses and shipment cost from each factory to each warehouse is given. GA is a meta-heuristic to search a population, iterating through generations until the fitness no longer gets better. This fitness of the population is considered to be the optimized solution for the problem.

Many problems have a static fitness function against which a population is examined. The search results in a single solution. This paper discusses the case of pigeons feeding on lentils – acase of dynamic fitness, where each result gives rise to a new problem.

Keywords: *Genetic Algorithm, Mutation, Crossover, Selection, Population, Dynamic Fitness, Changing Environment*

1. INTRODUCTION

Figure 1: Pigeons feeding on lentils at Jaipur, India (May, 2016)

Pigeons and other birds are fed in different parts of the world. Grains or lentils are thrown on the floor (feeding ground) by visitors which lands at random positions.When hungry pigeons feed, they find a suitable path based on density of lentils and relative distances.

The density and distances of lentils on the ground change as the pigeons feed. Hence, fitness changes as lentils are consumed. Visitors also contribute to the changing fitness as they randomly throw more lentils. This paper attempts to simulate the path of the pigeons feeding lentils on a ground using Genetic Algorithm with certain defined fitness criteria or functions.

2. RELATED WORK

Artificial Intelligence is built on swarm behaviour. Biological swarms such as that of fish, bees and birds show adaptation to changing environments or in dynamic situations such as propagation. A swarm is thought to be a single large intelligence that exceeds the intelligence of each individual in the population. Attempts are being made to study how these systems adapt to changing environments. Swarm intelligence is a study in itself and is an evolutionary algorithm. Ant Colony Optimization is one such study used to make approximations on optimization problems. Marco Dorigo in his book Ant Colony Optimization has applied ACO to solve the Travelling Salesman Problem.In recent years, studies and experiments are being done by using genetic algorithm on simulated biological environments that may provide better insight into changing systems.

3. METHODOLOGY

3.1. Problem Statement

How would a pigeon or a flock of pigeons on the ground navigate to feed on lentils spread out randomly ?

Certain assumptions are necessary in order to develop a problem definition and the fitness function.

3.2. Assumptions

1. The pigeons are already on the ground.
   - **a) Use:** This would help us decide a starting point for each pigeon.
   - **b) Real life:** It is possible that flying pigeons select regions which have a high density of lentils when they land to feed.
2. The pigeons do not analyze the entire field for food and its density. They simply look around and analyze closer regions.
   - **a) Use:** This would help us scan data in regions closer to the pigeon improving the program performance.
   - **b) Real life:** It is possible that pigeons behave based on group behaviour and on individual strengths and weaknesses. Individual pigeons may tend to navigate towards the flock.

3.3. Problem Definition

Based on the above assumptions, we define the navigation pattern of pigeons as "moving towards regions of high density of lentils by travelling the least possible distance". This gives us two fitness criteria: *a*) minimizing the distance of travel *b*) maximizing the density of lentils.Pigeons are not attracted to either fitness independently, but as a combination.The below screen shot shows an example of an initial state of the experiment, where a lentil is marked as a dot and the pigeon is a coloured ring.

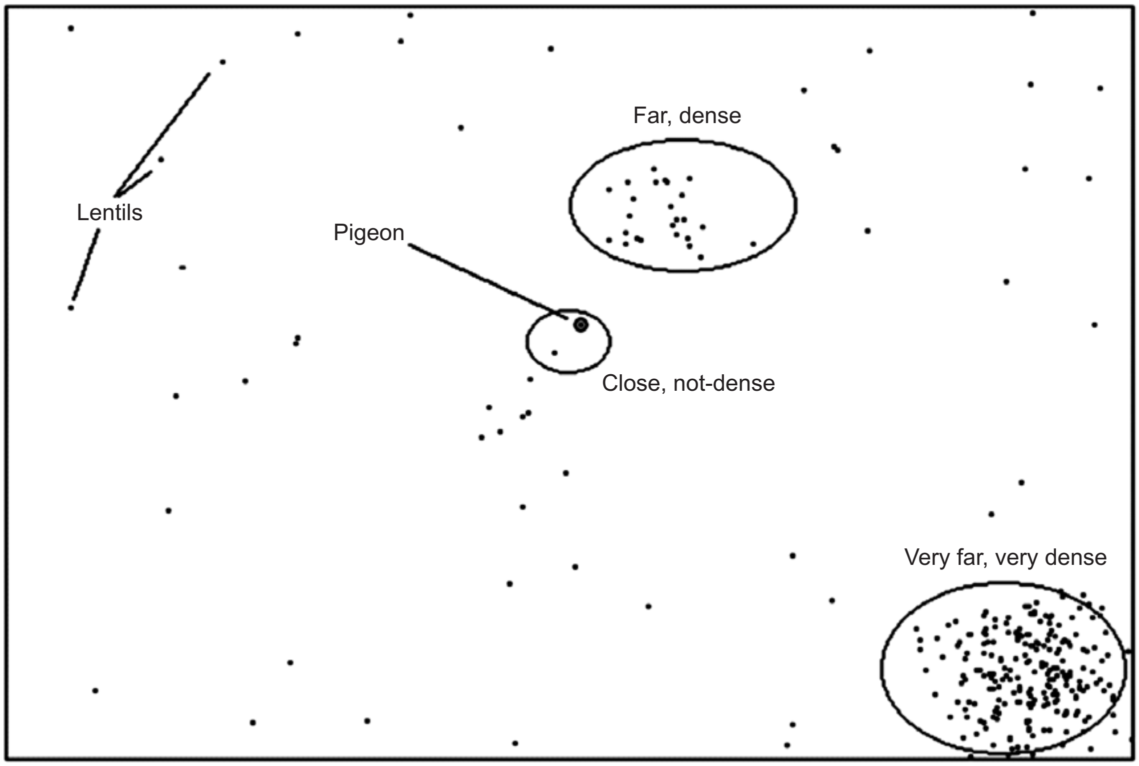

Figure 2: Screenshot showing the objects in the environment

3.4. Fitness function

We define the fitness function as:

$$\frac{\sum_{i=2}^{m} \rho_i}{\left(\sum_{i=2}^{m} d_i\right)^2}$$

where,

m is the length of the individual (an array of lentils that define the path)

ρ is the density around lentil i

d is the distance defined by $d_i = \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}$, where (x, y) is the coordinates of the lentil

Note on Denominator : The denominator is squared to eliminate the discrepancy created by direct proportion as indicated in the table below:

Table 1
Choice of fitness function

Path	*Density (ρ)*	*Distance (d)*	*ρ / d*	*ρ / d²*
A	20	10	2	0.2
B	10	5	2	0.4

Although both paths have the same density to distance ratio, path B is better as the same ρ / d ratio can be achieved by travelling lesser. Hence, a path is more fit if it has a greater ρ / d^2 value.

4. GENETIC ALGORITHM

Individual : An individual in the population is a sequence of lentils which defines the path of the pigeon. This experiment creates individuals of 6 lentils (current lentil + 5 lentils), each lentil denoted by its position in the array. The criterion of selection of an element in an individual is“any one random lentil from the closest five lentils if it hasn’t been already added to the individual”. In the image below, the pigeon is positioned at lentil 27. An example of an individual is [27, 9, 10, 23, 45, 28].

Table 2
Creation of an individual in the population

Element No.	*Current Lentil*	*Nearest 5 Lentils*	*Randomly selected Lentil*
0^{th}	27	9, 12, 8, 17, 6	9
1^{st}	9	12, 30, 3, 10, 18	10
2^{nd}	10	*n*, *n*, *n*, 23, *n*	23
3^{rd}	23	*n*, *n*, 45, *n*, *n*	45
4^{th}	45	28, *n*, *n*, *n*, *n*	28
5^{th}	28	–	–

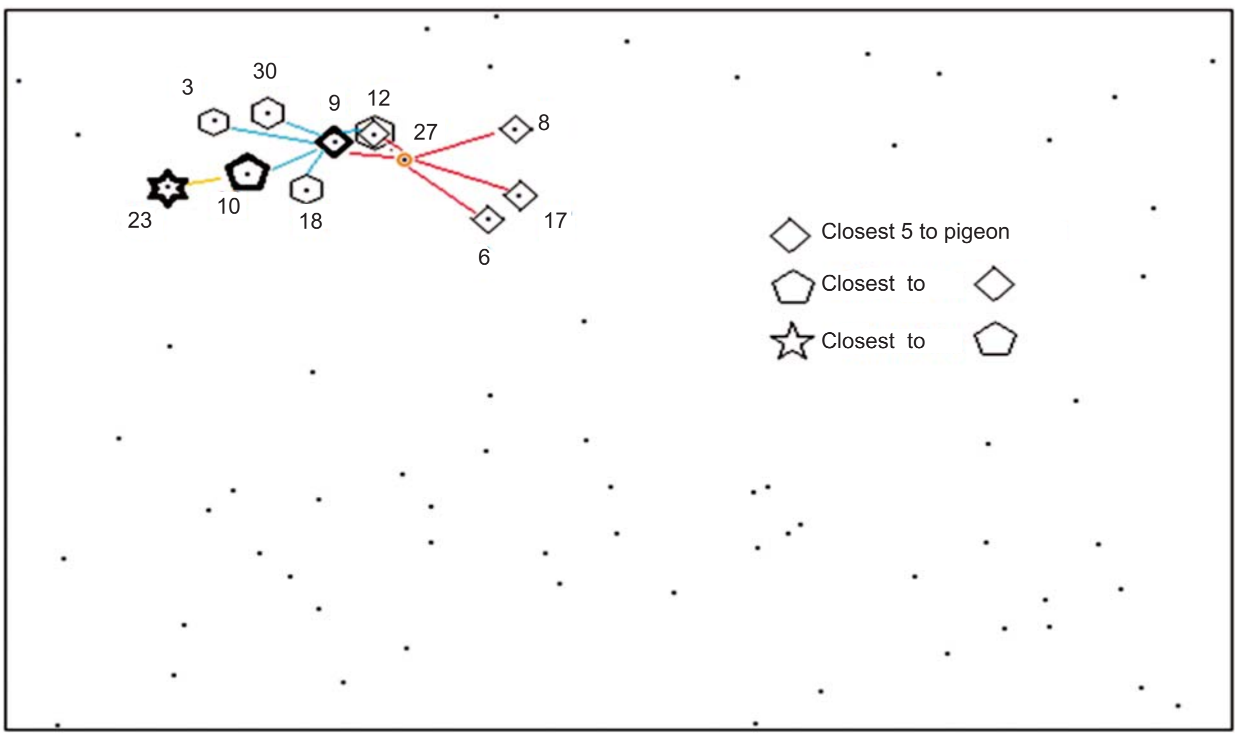

Figure 3: Screenshot depicting the creation of an individual

Density radius: This experiment calculates the density of lentils in a radius of 50px around each element (lentil) in the array (expect the 0^{th} element).

Population-size: This experiment uses a population of 10 individuals. As the individuals were not completely random and were already based on shortest distance, it was found that having a larger population did not contribute significantly to better results.

Parents and children: Parents selected for a *uniformcrossover* were from the fittest 50% of the population. One child was produced and *scramble mutation*(on elements other than the 0^{th}) was carried out on the child. If the child was fitter than the fittest parent, it was added to the population in replacement of the least fit individual in the population.

Uniform crossover[3]:A uniform crossover has a mixing ratio of 0.5. The offspring has approximately half its data from each parent. At each point, a choice is being made if data should be copied from the father or the mother. In our case, a child must have a unique path without data repetition. If both the data at the current position in the parents already exists in the child, the process is aborted. The below shown is an example of uniform crossover applied in this simulation.

Parent 1 :	27	9	10	23	45	28
Parent 2 :	27	1	12	30	3	10
Child 1 :	27	1	10	30	3	28

Scramble Mutation [5] :A scramble mutation is performed by selecting random alleles and interchanging their positions.In our case, the first element is the current position and must not be scrambled.

Child 1:	27	1	10	30	3	28	→	27	28	10	30	1	3

Generations : If the fitness did not change in 50 generations,the individual with the highest fitness was selected for navigation.

Navigation and re-evaluation : It must be noted that only the second element in the selected individual is used for navigation. The rest of the data (elements) in the individual is discarded. The reasons are:

1. With multiple pigeons,two pigeons can cross paths and hence making the path of the second pigeon invalid.
2. As lentils are consumed in various regions, it not only increases the distance between lentils, but also reduces the density.This changes the fitness completely. A re-evaluation becomes necessary.

Multiple pigeons – round-robin feeding: When multiple pigeons are added to the simulation, they feed in a round-robin way each getting one lentil at a time.

5. RESULTS AND DISCUSSION

This experiment successfully simulates a case of adapting to changing fitness using Genetic Algorithm. The simulation shows a certain level of intelligence in the following aspects :

1. Pigeons do not eat by choosing closer grains through a meticulous calculation. They may skip grains in order to move to denser regions and return back to feed on the skipped ones when the density has dropped relatively.
2. Pigeons do not navigate directly to very dense regions if it is not at an attractively short distance.
3. When multiple pigeons feed in the same region, they appear to compete for lentils until the region in which they are competing becomes less dense than the surrounding regions. At this time, the competing pigeons part ways to different regions.

The simulation is screen recorded (webm) and presented with this paper – Single pigeon (Sim1.webm), Multiple pigeons (Sim2.webm) and Adding lentils and pigeons in runtime (Sim3.webm).

Swarms come about from the interaction of large number of individuals in an ever changing environment competing for resources such as space, food or water. These resources are the constraints and these constraints keep changing with time. Hence, it becomes essential to quickly adapt to the changing fitness demand of the environment. Study of behaviour of swarms such as this provides insight into optimizing in a changing environment.

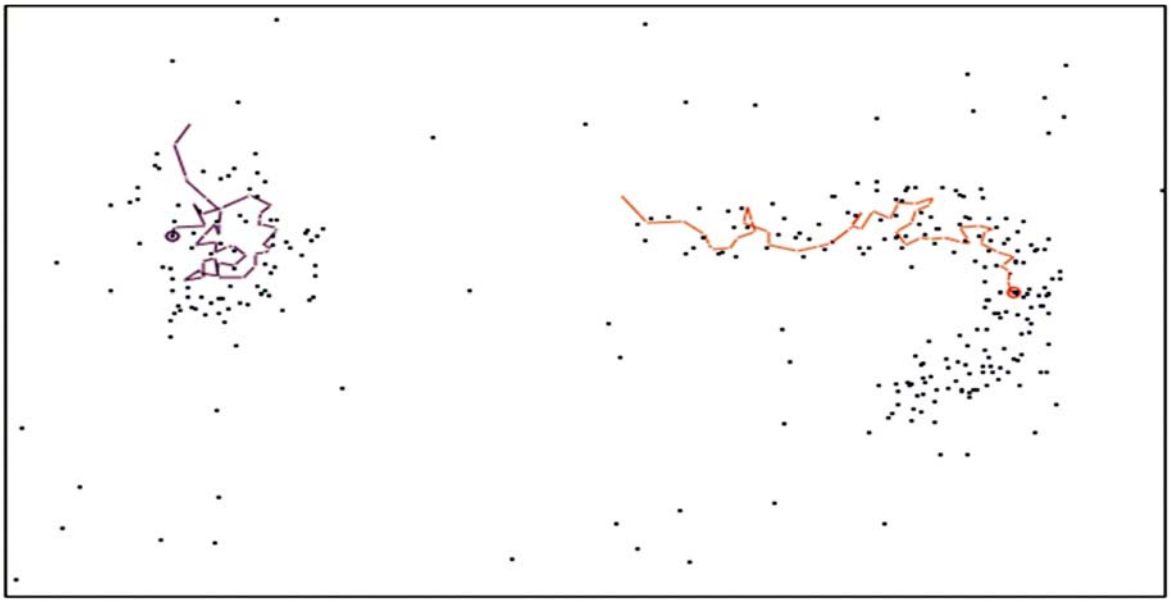

Figure 4: Simulation screenshot: Two pigeons feeding in different regions

6. CONCLUSION

Changing environments are very common and adapting to changing fitness can be seen in the behaviour of ants, bees and birds which is also referred to as swarm intelligence. GA simulations such as this one may provide inspiration to find solutions where there is a continuous change in the environment and optimization is an ongoing process, such as manufacturing and medicine (e.g. dealing with drug-resistant bacteria).

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