

**Habib University**  
**Computational Intelligence - CS 451**

**Assignment 02 - Report**  
**Swarm Intelligence**



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# 1 Question 1 - Graph Coloring Problem using Ant Colony Optimization

## 1.1 Introduction and Problem Formulation

The Graph Coloring Problem is a well known problem in Computer Science that asks a really simple question, "What is the minimum number of colors required to color a graph such that no two adjacent vertices have the same color?". This problem is NP-Hard, a combinatorial optimization problem, and has a lot of real world applications. The image below shows a graph and its corresponding coloring.

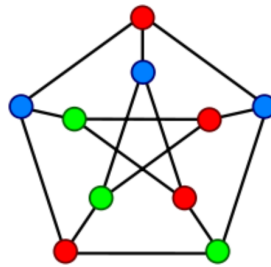


Figure 1: Graph Coloring Example

In this assignment, the Ant Colony Optimization (ACO) Algorithm is used to efficiently provide a solution for coloring of a graph with minimum number of colors. The ACO algorithm is a probabilistic technique for solving computational problems which can be reduced to finding good paths through graphs. The ACO algorithm is inspired by the foraging behavior of ants and is a class of optimization algorithms that are based on the behavior of ants.

The problem can be formally formulated as follows:

**Definition 1.1** Given a graph  $G = (V, E)$ , where  $V$  is the set of vertices and  $E$  is the set of edges, a  $k$ -coloring of  $G$  is a mapping such that  $c : V \rightarrow \{1, 2, 3, \dots, k\}$  is a mapping from the set of vertices to the set of colors such that  $\forall u, v \in V, \{u, v\} \in E$  where  $\{u, v\}$  represents an edge from vertex  $u$  to vertex  $v$ ,  $c(u) \neq c(v)$ . The objective is to find the minimum value of  $k$  such that a  $k$ -coloring of  $G$  exists.

We invoke the help of a theorem in Graph Theory for our implementation which makes things much easier for us, and helps us get to the solution faster. The theorem is as follows:

**Theorem 1.1** If  $G$  is a simple graph with the largest vertex degree  $\Delta$ , then  $G$  is  $(\Delta + 1)$ -colorable.

The above theorem is used in the color assignments, due to which the color assignment is initially sub-optimal, and not equal to the number of nodes, thus we get to an optimal solution much faster.

## **1.2 Implementation of the Ant Colony Optimization Algorithm**

### **1.2.1 Parameters**

### **1.2.2 Graph Class**

### **1.2.3 Ant Class**

### **1.2.4 Ant Colony Class**

## **1.3 Results and Analysis**