# Sequencing Aircraft Landings by Genetic Algorithms


**Alexis Guigue**
Laboratoire d'optimisation Globale
7, Avenue Edouard Belin
31055 Toulouse, France
guigue@recherche.enac.fr
Tel : + 33 5 62 17 41 83

**Sofiane Oussedik** *
Centre de Mathématiques Appliquées
Ecole Polytechnique
91128 Palaiseau Cedex, France
oussedik@cmapx.polytechynique.fr
Tel : + 33 1 69 33 46 65

**Daniel Delahaye** †
Laboratoire d'Optimisation Globale
7, Avenue Edouard Belin
31055 Toulouse, France
delahaye@cmapx.polytechnique.fr
Tel : + 33 5 62 17 41 52


## 1 PROBLEM DEFINITION

We consider the problem of scheduling aircraft landings at an airport with only one runway. This problem is one of deciding a landing time for each plane such that each plane lands within a predetermined time window and separation criteria between the landing of a plane and the landing of all successive planes are respected (wake vortex constraint). The objective to be maximized is the use of the runway (Air Traffic Control preference point of view : having maximum landings during any time period).

The problem that can be polynomially reduced to a Job Shop Scheduling problem is NP_Hard.

## 2 GENETIC ALGORITHMS MODELING

Each chromosome represents a sequence of landing planes. No speed values (and deduced landing times) are given yet but each chromosome fixes a sequence of planes. The goal of the GA is to find the best sequence (permutation) of planes. The landing time of each plane on each chromosome is determined by a greedy deterministic algorithm that optimize the runway feeding. The Recombination Operators are a crossover derived from the Traveling Salesman GA modeling and a mutation that randomly shifts (local mutation : shifts neighborhood planes ; global mutation : random shifting) two or more aircraft in the sequence. The fitness function represents the minimization of the time when the runway is available and no plane lands on it added to a penalization term depending on the GA iteration and on the length of the unfeasible sequences (if any) in the chromosome.

* Eurocontrol Experimental Center, Bretigny, France

† Centre d'Etudes de la Navigation Aérienne. 7, Avenue Edouard Belin, 31055 Toulouse, France

## 3 RESULTS

The computations were based on a data set that involves 43 planes. All planes are of the same type and have the same possible time steps moving periods in the past and in the future and the same speed restrictions. The planes have initial positions belonging to the $[40, 140]$ nautic miles interval from the gate (the gate is the runway entry point).

This data set is chosen in order to have a problem where a trivial optimal solution is known which depends clearly on the aircraft distances from the gate.

We usually obtain near optimal solutions that are at a distance of one or two permutations from the needed optimal solution. These permutations concerns flights that are at a nearest distance from the gate.

Parameters, like the population length (1000 chromosomes) and well chosen global and local mutation probabilities leads to good solutions. Also, the use of the mutations combined with a well defined crossover leads fast ($\sim$ 20 iterations that corresponds to $\sim$ 8 minutes on a Pentium 200 Mhz) to very good solutions. Then, the combined effect of adaptive mutations and crossover seems to be the most efficient strategy.

**References**


J. Abela, D. Abramson, M. Krishnamoorthy, A. De Silva and G. Mills (1993), *Computing optimal schedules for landing aircraft*, Proceedings 12th National ASOR Conference, Adelaide, Australia, 7190.

R.G. Dear and Y.S. Sherif (1991), *An algorithm for computer assisted sequencing and scheduling of terminal area operations*, Transportation Research Part A Policy and Practice 25, 129139.

H.N. Psaraftis, *A dynamic programming approach for sequencing groups of identical jobs*, Operations Research 28, 13471359 (1980).