Three-Dimensional Offline Path Planning for UAVs Using Multiobjective Evolutionary Algorithms

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Introduction

We aim to solve the following two problems:

1. 3D offline path planning over a known terrain with no other restrictions
2. 3D offline path planning over a known terrain, where the vehicle has to pass through one or more pre-specified points in the space.

Objective functions

1. Length of the path
2. Risk factor: this takes into account the objective that the vehicle should fly as far as possible from the ground obstacles.

Constraints

1. The vehicle should not collide with the terrain boundary in the course of its flight.
2. The UAV should not perform abrupt changes of direction. We impose this constraint by requiring that the angle between the two successive discrete segments of the curve should not be less than a certain cutoff angle.
3. The overall maximum height of any point in the curve should not exceed a specified upper limit.

Representation of UAV Path

The UAV path is represented using B-Spline curves. Such a representation has several advantages:

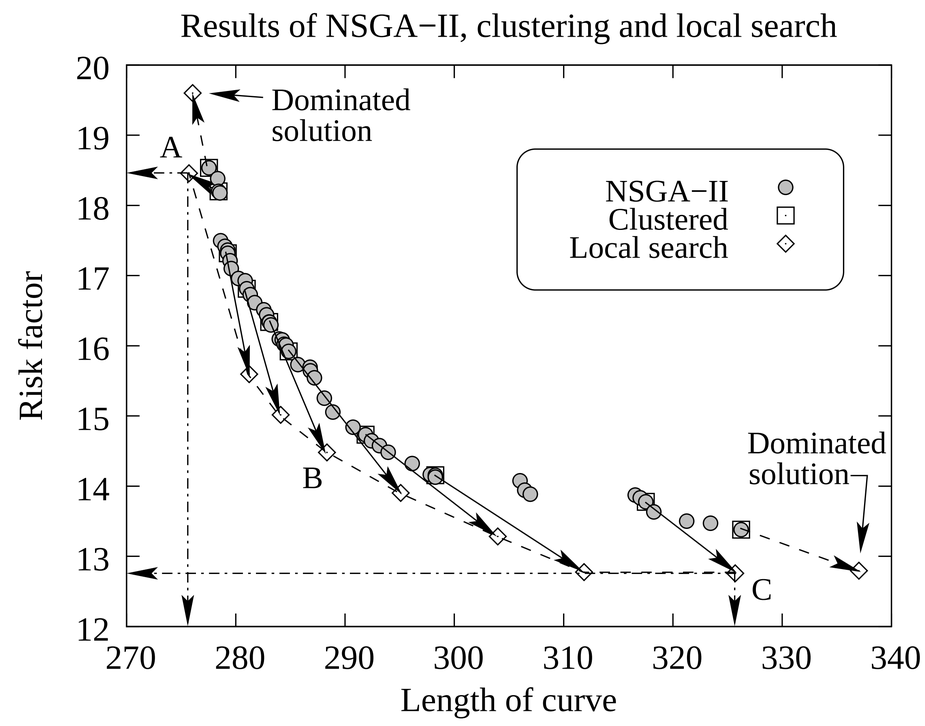
1. B-Spline curves can be defined by using only a few *control points*, this makes it encoding for GA easier.
2. Very complicated, smooth paths can be produced using a few control points, and the resulting curve is differentiable up to the first order.
3. The paths for the second problem can also be represented using B-Spline curves, by a suitable fix-up of the control points.

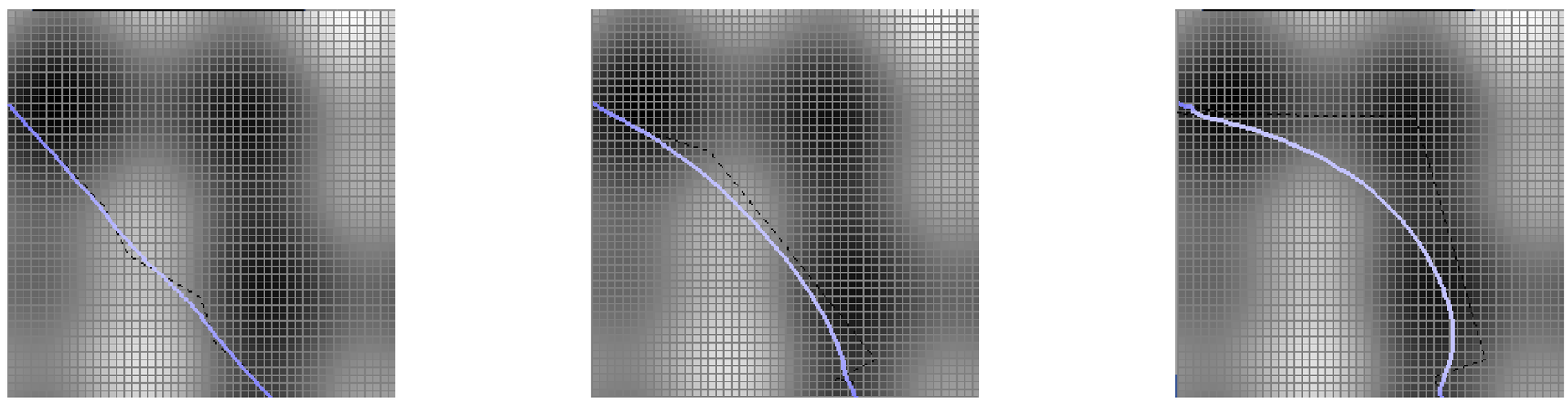
The Path Planning Procedure

1. **NSGA-II algorithm**: We use NSGA-II algorithm to find several trade-off non-dominated solutions for the two given objective functions, subject to the three constraints. The control points of the B-Spline curve are encoded using real numbers. SBX crossover operator is used.
2. **Clustering**: K-mean clustering us used to find 8 or 10 representative solutions from the non-dominated front obtained using the NSGA-II algorithm.
3. **Local Search Procedure**: From each of the 8-10 solutions obtained after the Clustering algorithm, a local search using hill climbing procedure is performed to further get an improvement in the objective function values.

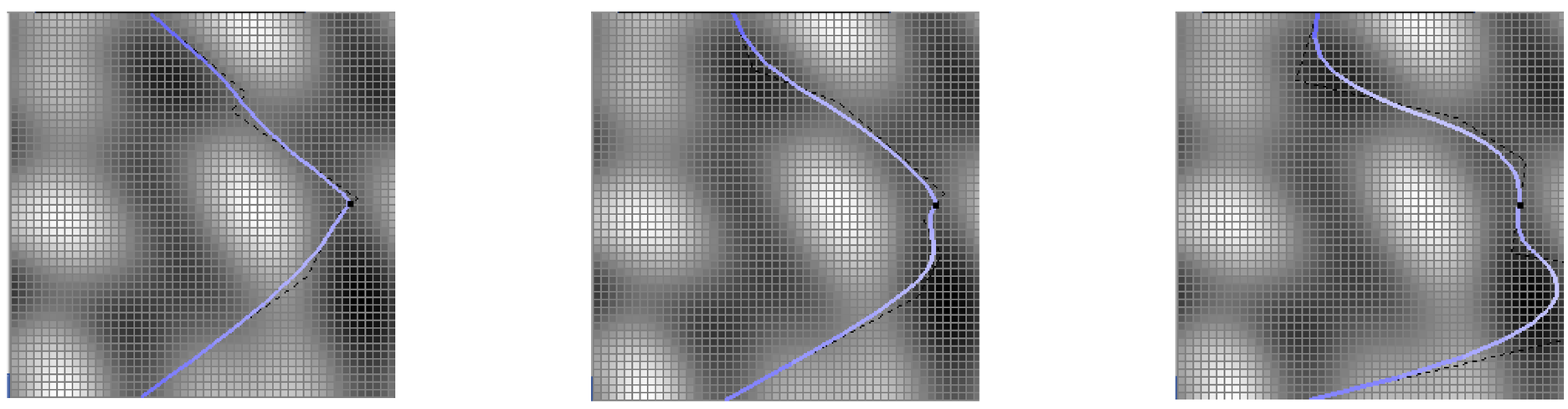
Simulation Results

Type 1 problem:





Paths obtained for a problem of Type 1. The three paths reflect the trade-off between the length of the path, and the risk measure. The first path is shortest, but risky as it goes near the peak of the hill. The last path is long but the safest, since it avoids the hilly region.



Paths obtained for a problem of the second type. The point through which the UAV has to pass is shown with a black dot.