Risk-based Path Optimization for UAVs Operating over Inhabited Areas

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Operating unmanned aerial vehicles (UAVs) over inhabited areas creates a risk to third-parties on the ground.

The risk measure is the expected number of fatalities. The risk along a segment between two points depends upon the probability that the aircraft will crash during that time, the lethal crash area, and the expected population density along that segment:

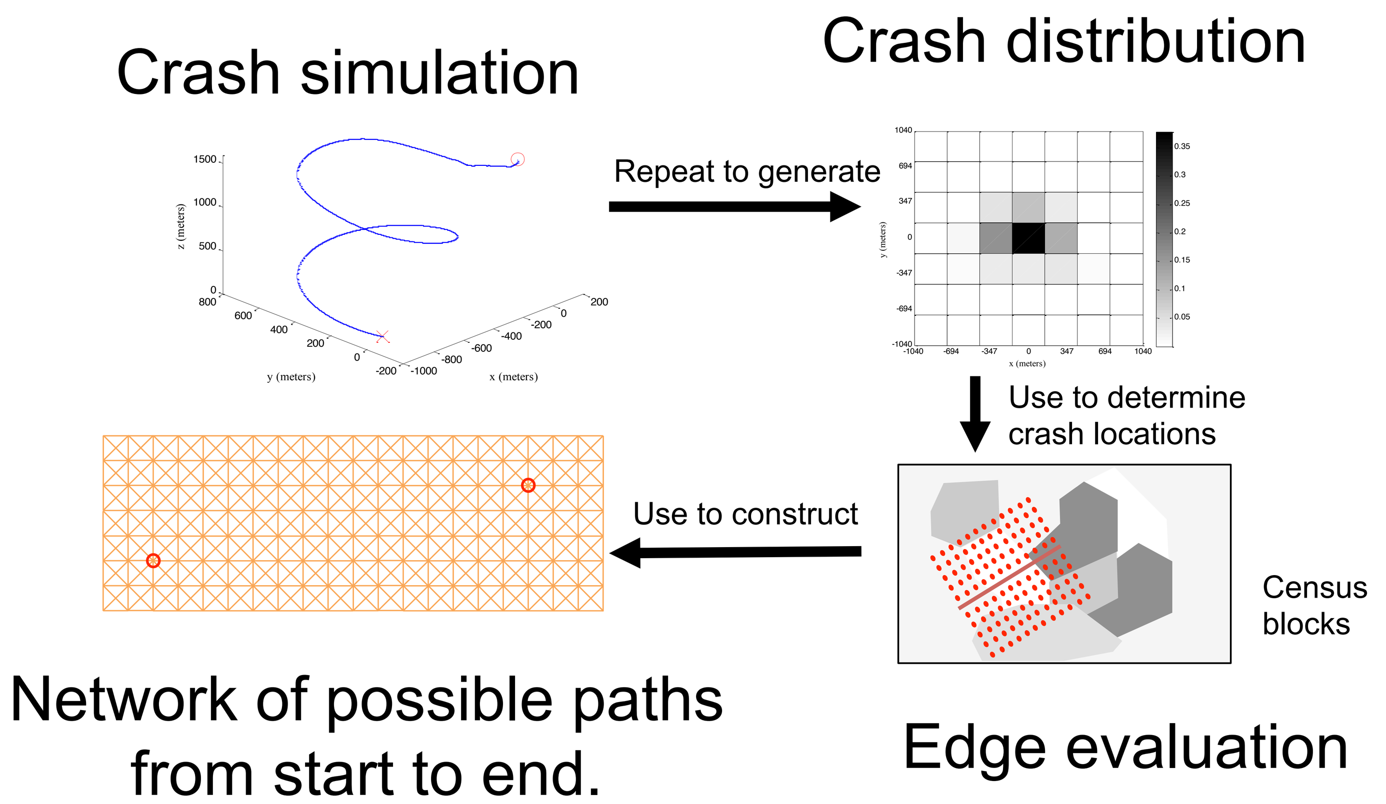
$$r(i,i+1) = t(i,i+1)\left(\frac{K_1}{100,000}\right)K_2\bar{D}(i,i+1)$$

Optimizing UAV paths requires considering both time and risk.

The approach calculates the time and risk associated with each edge in a network of possible paths and then solves a shortest path problem on that network.

The objective function is a weighted sum of the total time and total risk.

$$f(X) = w_t\sum_{i=0}^{n}\frac{t(i,i+1)}{\bar{t}} + w_r\sum_{i=0}^{n}\frac{r(i,i+1)}{\bar{r}}$$

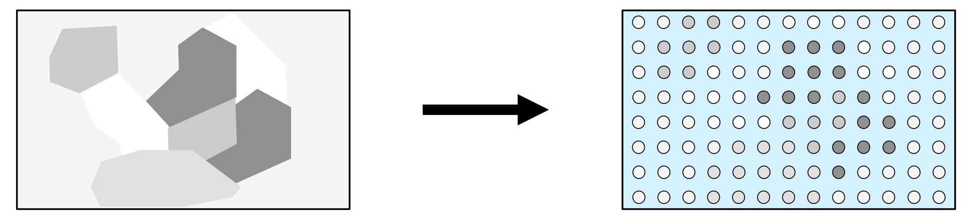


Our grid-based approach reduces the computational effort.

Population density calculations can be based on a grid of points instead of examining the polygonal census blocks.

Using the population density grid can significantly reduce (over 90%) the computational effort required to estimate risk with small impact (less than 1%) on risk estimate.

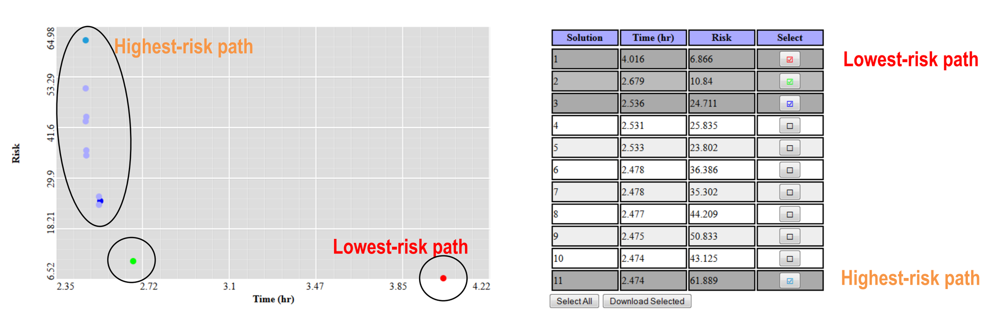
Census blocks or tracts → Population density grid



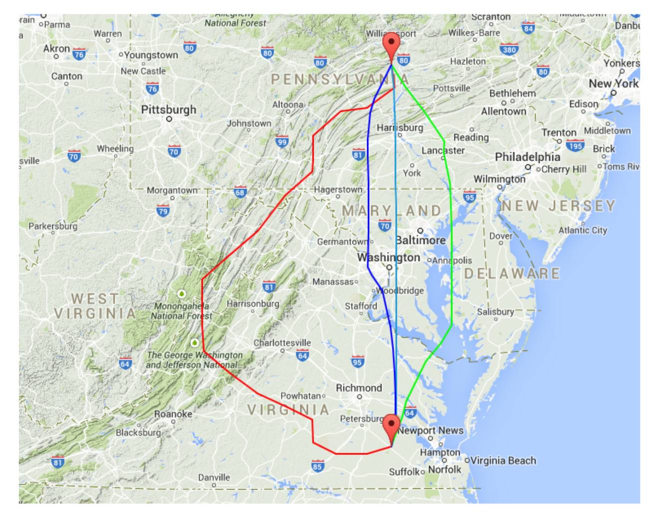
Our prototype software displays the time vs. risk tradeoff curve and the path options.

The problem is solved with different values of weights to generate a set of solutions. The lowest-risk solutions often take long routes through areas with lower population density; the shortest routes go through high-density areas, which increases risk.

Risk vs. Time Tradeoff



Map showing selected paths



Publications

- Rudnick-Cohen, Eliot, Jeffrey W. Herrmann, and Shapour Azarm, Risk-based path planning optimization methods for UAVs over inhabited areas, DETC2015-47407, Proceedings of the ASME 2015 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference, IDETC/CIE 2015, August 2-5, 2015, Boston, Massachusetts.
- Rudnick-Cohen, Eliot, Jeffrey W. Herrmann, and Shapour Azarm, Risk-Based Path Planning Optimization Methods For Unmanned Aerial Vehicles Over Inhabited Areas, ASME Journal of Computing and Information Science in Engineering, Volume 16, Number 2, June, 2016. doi: 10.1115/1.4033235.
- Rudnick-Cohen, Eliot, Shapour Azarm, and Jeffrey W. Herrmann, Multi-Objective Design and Path Planning Optimization of Unmanned Aerial Vehicles (UAVs), 16th AIAA/ISSMO Multidisciplinary Analysis and Optimization Conference, Dallas, Texas, June 22-26, 2015.

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