CHESS

CENTER FOR HYBRID & EMBEDDED SOFTWARE SYSTEMS

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# Model-based design for safe UAV landing

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## Abstract

Use reachable safe-sets to guarantee that a fixed-wing UAV may land safely, given a stationary target and initial conditions.

## Challenge Problem

If a fixed-wing UAV following its glideslope is directed off its landing path, and after some time is redirected to land, can the decision to safely land be guaranteed as true?

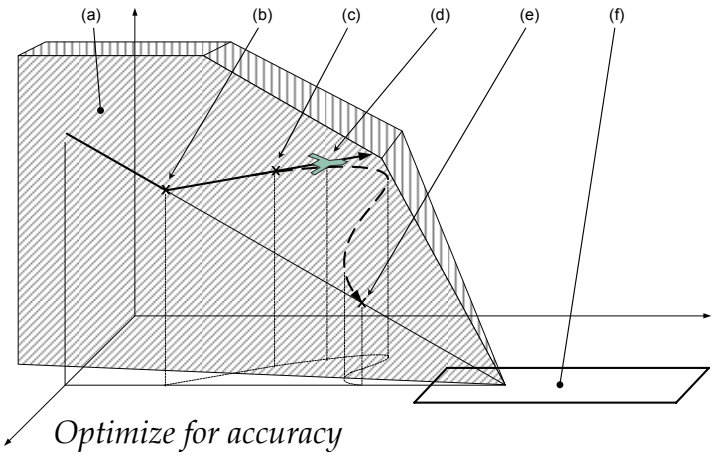
## Technology

### *Start with safety*

Start with the region at landing, and calculate backward from there.

### *Level-set methods*

Using Mitchell's Toolbox for Level Set Methods, configure the problem in orthogonal dimensions (to speed up offline computation) and create safety lookup tables.

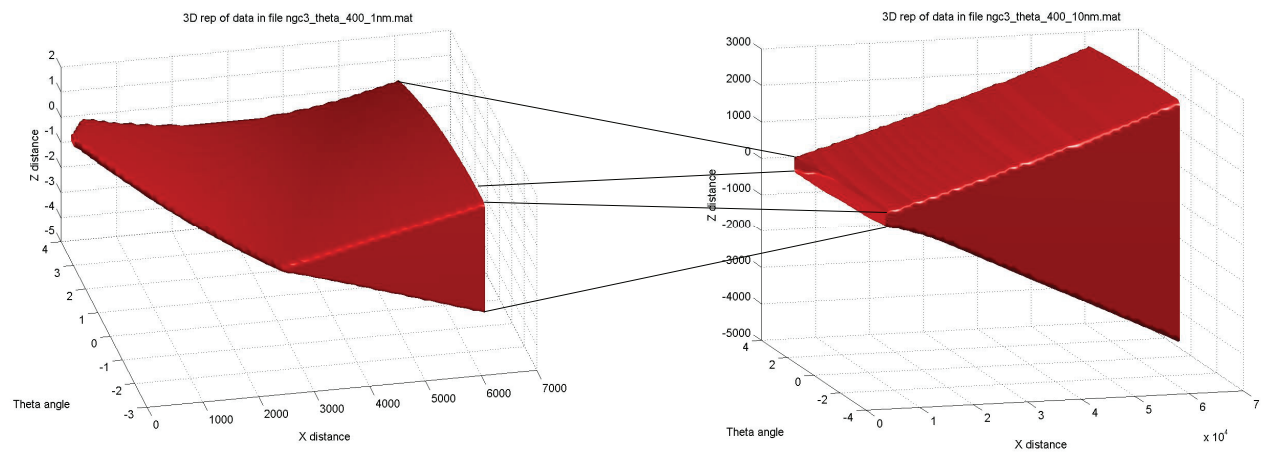



### *Optimize for accuracy*

Treat more complex portions of the reachable space with more care, and increase the "step size" for more uniform portions of the space. Then, glue these together during the executable generation.

### *Generate executable*

With the lookup tables available, generate a runtime executable from the tables which will give a conservative answer of safety is less than 10-ms.




## Testing

Flown on T-33 Trainer jet in conjunction with DARPA SEC Capstone demonstration, as well as enormous offline regression testing.

## Benefits

For a UAV:

- reduced stress and decision load for remote pilot
- less aircraft training required
- hyper-accurate safe-set calculations can be performed

For families of aircraft,

- train on one aircraft, familiar with procedure on all
- computational requirements independent of aircraft
- uniform integration strategy for technology
- multiple versions of safe sets for
  - time of war
  - hazardous conditions
  - emergency landings

## References

[1] I. Mitchell, "Application of level set methods to control and reachability problems in continuous and hybrid systems," Ph.D. dissertation, Stanford University, Aug. 2002.

[2] —, ``A toolbox of level set methods,'' Department of Computer Science, University of British Columbia, Tech. Rep., 2004.

[3] C. Tomlin, I. Mitchell, A. Bayen, and M. Oishi, "Computational techniques for the verification of hybrid systems," *Proceedings of the IEEE*, vol. 91, no. 7, pp. 986—1001, July 2003.

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