Li XIE, Yi-qun Zhang, Jun-yan XU, 2020. Optimal two-impulse space interception with multiple constraints. *Frontiers of Information Technology & Electronic Engineering*, 21(7):1085-1107. https://doi.org/10.1631/FITEE.1800763

Optimal two-impulse space interception with multiple constraints

Key words: Space interception problems; Variational method; Multiple constraints; Two-velocity impulses; Multi-point boundary value problems; Local optimal solutions; Dynamic slackness variable method

Corresponding author: Li XIE
E-mail: lixie@ncepu.edu.cn
ORCID: https://orcid.org/0000-0002-5214-9769

Motivation

We consider optimal two-impulse space interception problems with multiple constraints, which come from practical requirements.

The multiple constraints are imposed on the terminal position of a space interceptor, impulse and impact instants, and the component-wise magnitudes of velocity impulses.

By this research, we answer some questions theoretically oriented, for example, under what circumstance does a true two-impulse optimal solution occur for our interception problems?

Main idea

In 1952, Arthur E. BRYSON Jr. told such a story about how the calculus of variations was involved in the aerospace field through the maximum range problem of a Hughes air-to-air missile.

We use variational methods to solve these optimal two-impulse space interception problems under consideration.

Method

1. Optimization problems are formulated as multi-point boundary value problems and solved by the calculus of variations. The Lagrange multiplier method is involved.
2. Slackness variable methods are used to convert all inequality constraints into equality constraints. A new dynamic slackness variable method is presented.
3. Boundary conditions of all interception problems are derived. MATLAB solvers are used to solve the resulting multi-point boundary value problems.

Major results

Our method is used to solve the two-impulse space interception problems of free-flight ballistic missiles.

A number of conclusions for local optimal solutions have been drawn based on highly accurate numerical solutions.

For example, by numerical examples, we find that when time and velocity impulse constraints are imposed, optimal two-impulse solutions may occur, and if two-impulse instants are free, then a two-impulse space interception problem with velocity impulse constraints may degenerate to a one-impulse case.

Major results (Cont'd)

E.g., numerical verification for multiple constraints

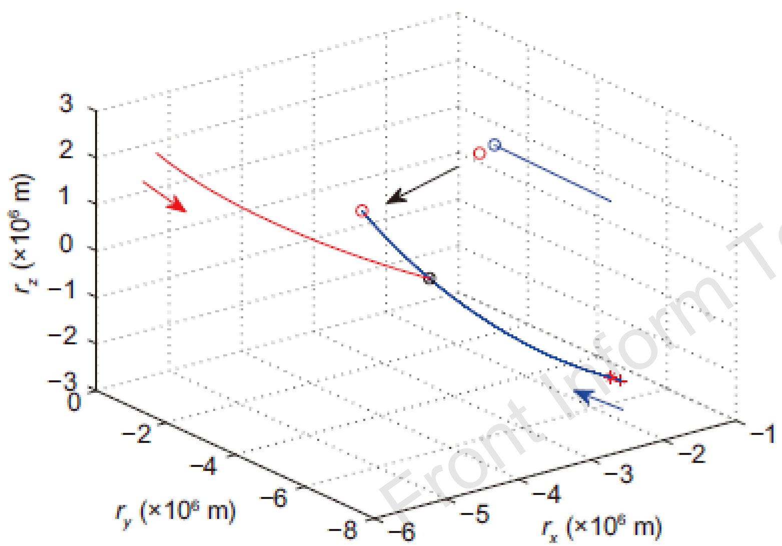

Fig. 15 Interception trajectory in Example 8 (symbols $*$ and $+$ correspond to the impulse instants, and $\circ$ and $\otimes$ correspond to the terminal instant of the interceptor and impact instant respectively)

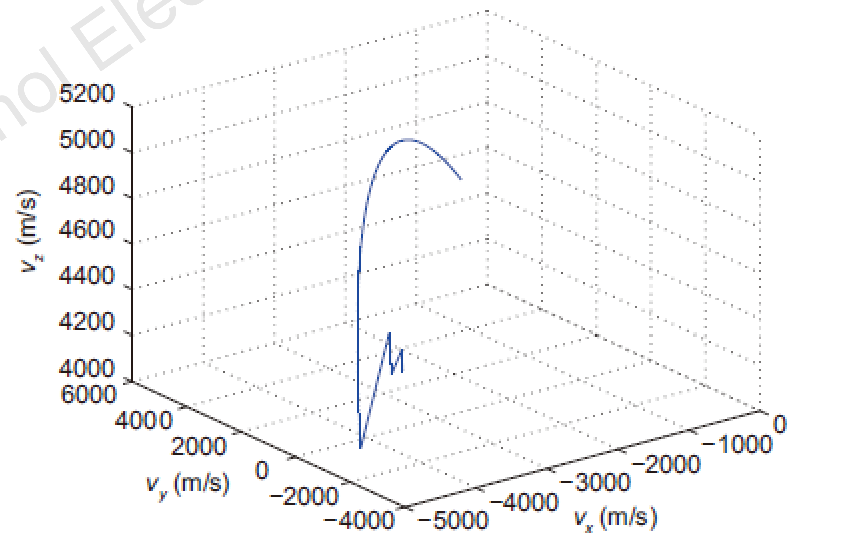

Fig. 17 Velocity vector of the interceptor in Example 8

Conclusions

Using the calculus of variations, we have solved two-impulse space interception problems with multiple constraints.

A number of conclusions concerning two-impulse ballistic missile space interception problems have been established based on highly accurate numerical solutions provided by MATLAB boundary value problem solvers.

Since in this paper, the calculus of variations as indirect methods provides only local optimal solutions, a future research would be to investigate global optimal solutions.