Low-cost rotary wing design applied to design optimization of roter blade for Mars helicopter

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Abstract

In the exploration of Mars using helicopters and portable uncrewd drones on the Earth, fortable rotor blades are utilized, because they must be foldable and compact. A low-cost blade evaluation method based on blade element momentum theory has been established, which assumes that the aerodynamic performance of the blade element is representative at 75% span position for high aspect ratio blades. However, it has been observed that this method yields results that deviate significantly from the result by high-fidelity computational fluid dynamics for Mars atomosphere. In this study, we investigated the optimal position of the representative airfoil section and the number of sections required to provide aerodynamic coefficients for the airfoil. We then used evolutionary computation to design an optimal drone for Mars exploration.

Reasons and benefits of using JAXA Supercomputer System

In this study, we conducted an optimal design using evolutionary computation. Since the design target is the sectional airfoil shape, a 2D airfoil evaluation is required for each design solution in addition to blade element momentum theory. Although the application of evolutionary computation became possible due to the low-cost evaluation method, which is based on the blade element momentum theory, it is necessary to use JSS3, as it is a numerical calculation governed by the Navier-Stokes equations. JSS3's capability is also required when conducting numerical calculations based on the immersed boundary method for confirmation purposes.

Achievements of the Year

Considering the deployment and storage, we examined the use of the corrugated airfoil for the blade cross-section as shown in Fig. 1. In the design of the corrugated airfoil, we considered the use of Efficient Global Optimization, a Bayesian optimization technique. However, issues such as overfitting in Gaussian process regression were observed, prompting us to start by examining the choice of kernels. Specifically, we varied the exponent, which is a user-defined parameter in the Matern kernel, and the search parameters for the acquisition function, attempting to find a design. Consequently, we identified a combination that seemed favorable.

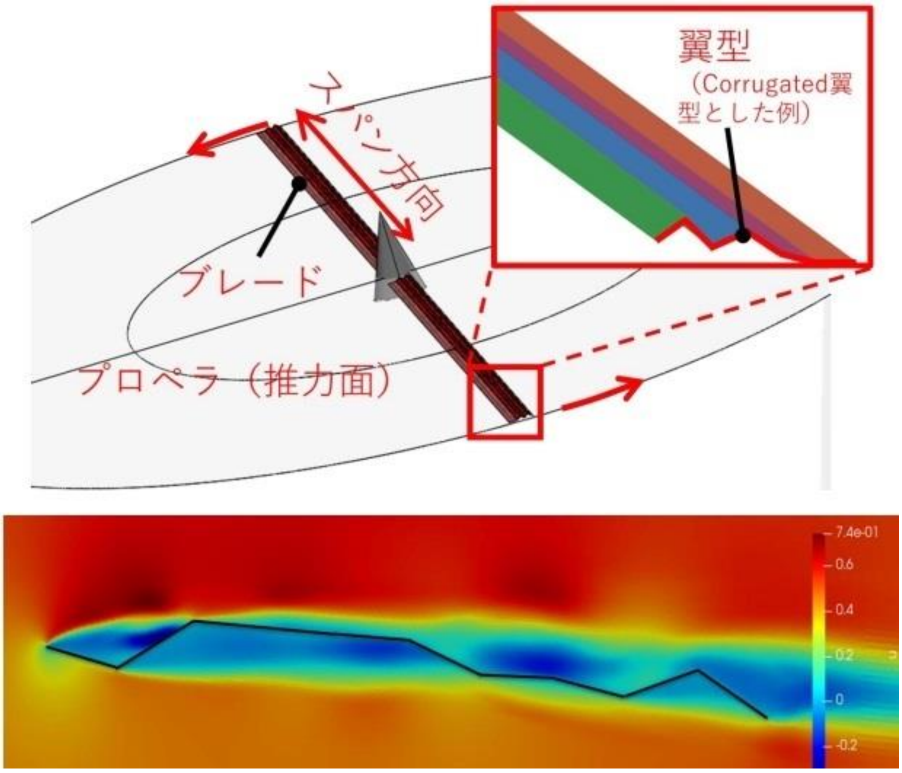

Fig. 1: Foilding blade consept with corrugated airfoil and CFD result for a corrugated airfoil.

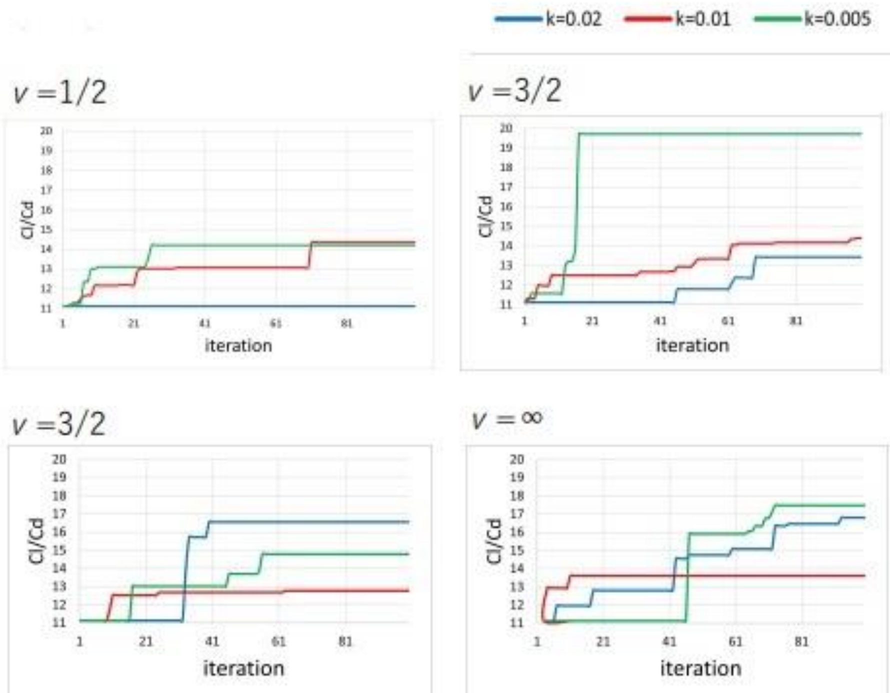

Fig. 2: Investigation for the Kernel parameters selection.

- **Publications**

N/A

- **Usage of JSS**
- **Computational Information**

Process Parallelization Methods	MPI
Thread Parallelization Methods	OpenMP
Number of Processes	32
Elapsed Time per Case	2 Hour(s)

- **JSS3 Resources Used**

Fraction of Usage in Total Resources*1(%): 0.01

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage*2(%)
TOKI-SORA	3,772.69	0.00
TOKI-ST	52,225.02	0.06
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	147.61	0.01
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage[*2] (%)
/home	0.00	0.00
/data and /data2	7,485.00	0.05
/ssd	0.00	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage[*2] (%)
J-SPACE	0.00	0.00

[*1]: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage[*2] (%)
ISV Software Licenses (Total)	67.37	0.03

[*2]: Fraction of Usage：Percentage of usage relative to each resource used in one year.