INTERNATIONAL HPC SUMMER SCHOOL 2017

# Fluid-Structure Interaction Analysis of Flapping Motions by Partitioned Iterative Coupling Method

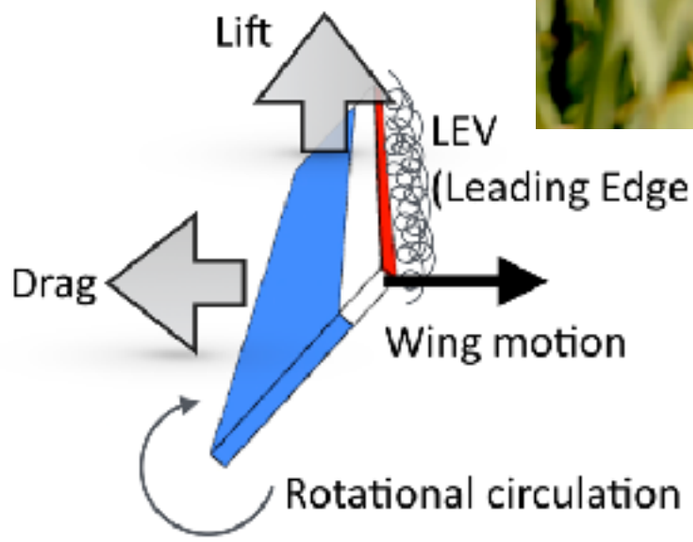
**Giwon Hong**, Tomonori Yamada, Naoto Mitsume, Shinobu Yoshimura

Department of Systems Innovation
School of Engineering
The University of Tokyo

C-8, Poster Session
Boulder, US
June 27 2017

# BACKGROUND & OBJECTIVE

[1]




## BACKGROUND

- Flapping flight is complex fluid-structure interaction (FSI) phenomenon
- Asymmetric and aperiodic flapping motion makes non-linearly deformed wings, and an unsteady flow follows. Pressure difference and vortices are generated, so beings can fly


[2]

## OBJECTIVE

- To optimize flapping motions by FSI analysis for designing micro air vehicles (MAVs)

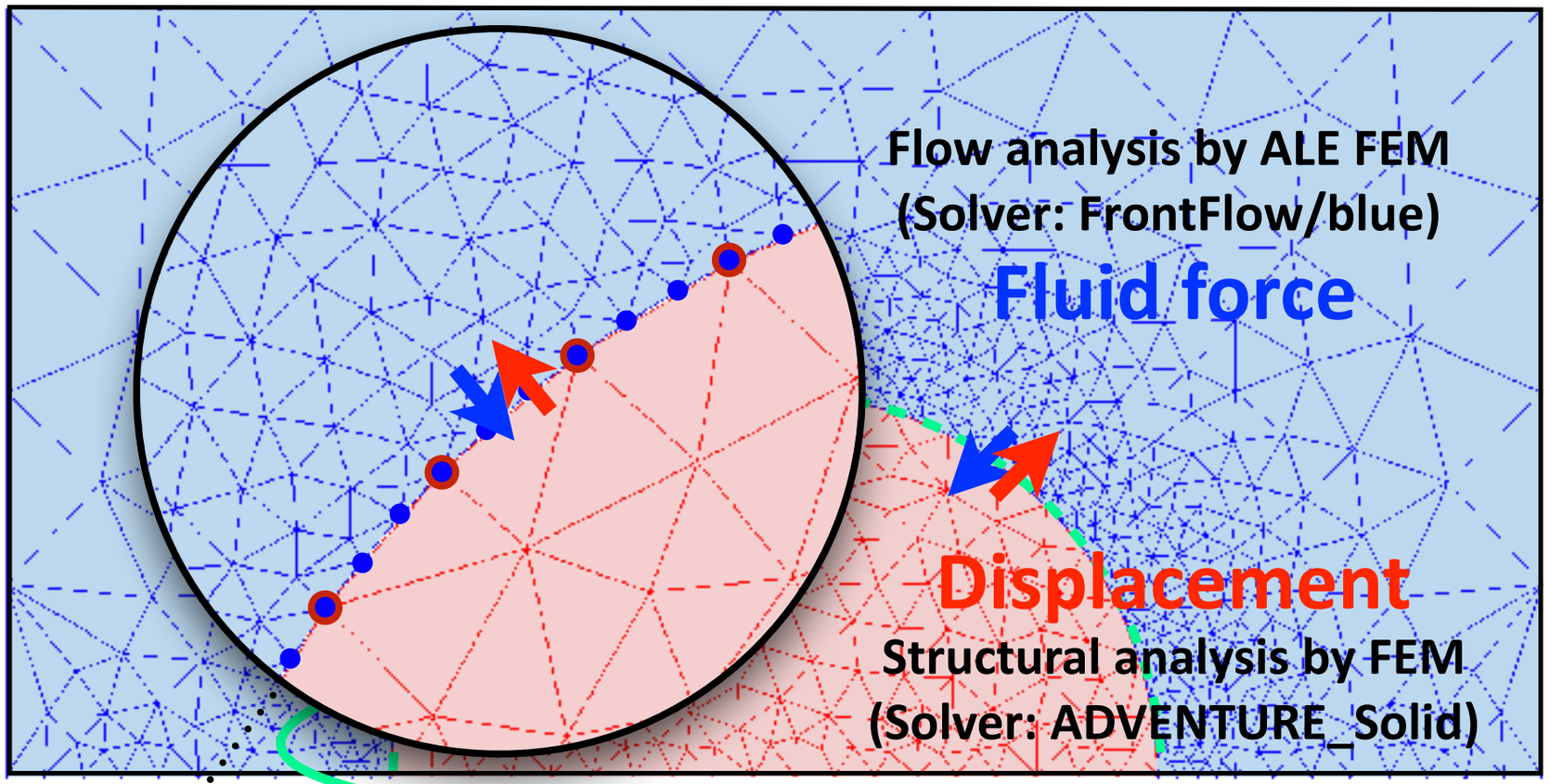
# Main Research Contents

1. To develop stable, applicable, and practical FSI analysis system by partitioned iterative coupling method
2. To optimize flapping flight in morphology and kinematics

[1] “Slow-motion video of hummingbird and insect flight helps solve hovering physics problem”, https://www.youtube.com/watch?v=HIigW8Ge4zo, Stanford University, 2015.
[2] “The 50 Best Inventions”, http://content.time.com/time/magazine/0,9263,7601111128,00.html, TIME 178(21), 2011.

# FSI ANALYSIS

- Flapping motion can be considered as **the interaction between an incompressible viscous flow and a non-linear elastic structure**
- **Partitioned iterative coupling method** [3] lets us to use exclusive solvers for flow and structural analyses, and to handle strong interaction problems



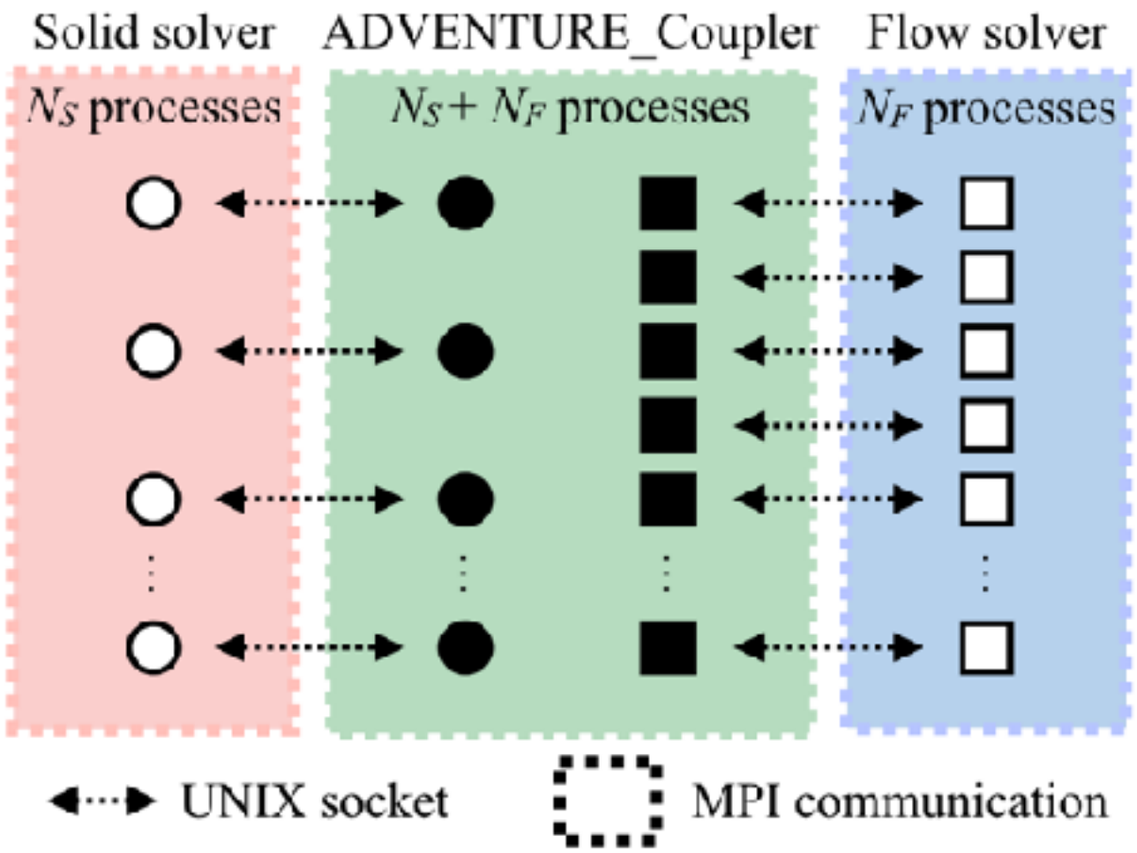

Concept of FSI problem


[3] T. Yamada, G. Hong, S. Kataoka, S. Yoshimura. Parallel partitioned coupling analysis system for large-scale incompressible viscous fluid-structure interaction problems. *Computers & Fluids*, 141, pp. 259–268, 2016.

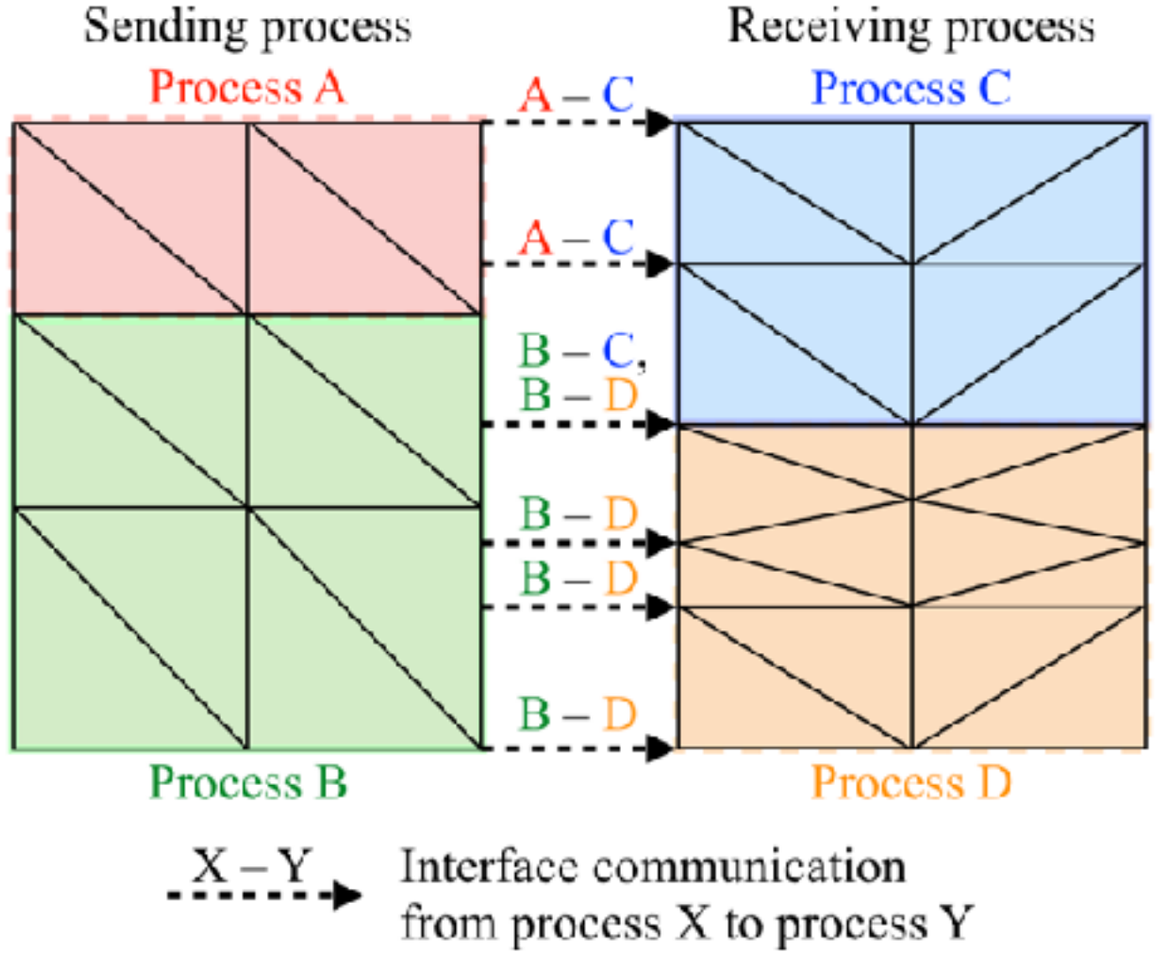
[4] T. E. Tezduyar, R. Benney. Mesh moving techniques for fluid-structure interactions with large displacements. *Journal of Applied Mechanics*, 70(1), pp. 58–63, 2003.

# PARALLEL COMPUTING ON THE SYSTEM

## COMMUNICATION




**Communication model of coupling analysis using ADVENTURE_Coupler**

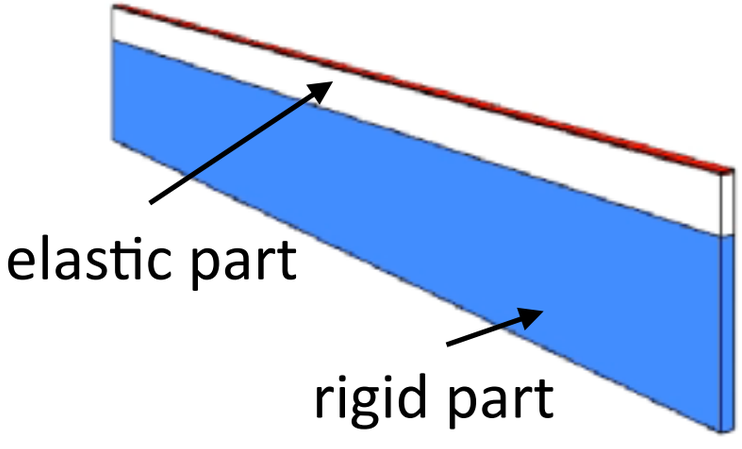



**Model of communication among processes of ADVENTURE_Coupler**

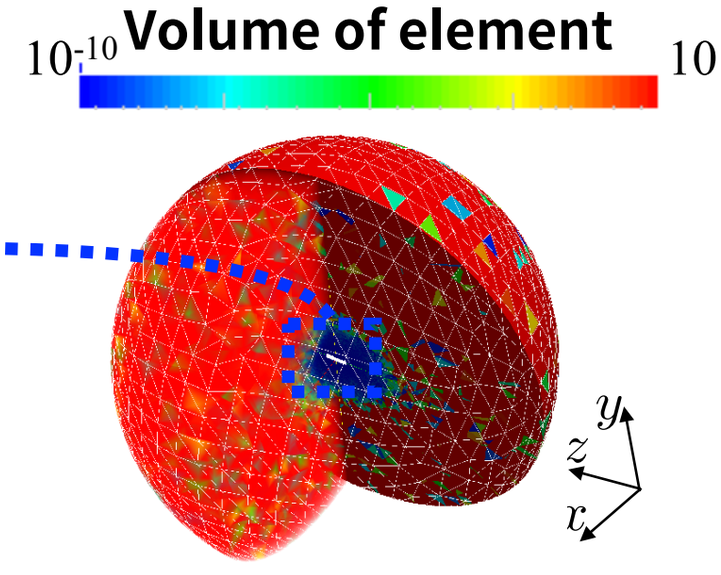
- UNIX socket is used for the communication between different softwares
- MPI communication is used on each analysis solver and the coupler for dealing with large-scale models where domain decomposition is applied

# RESULT AND ISSUE

## ANALYSIS PROCEDURE

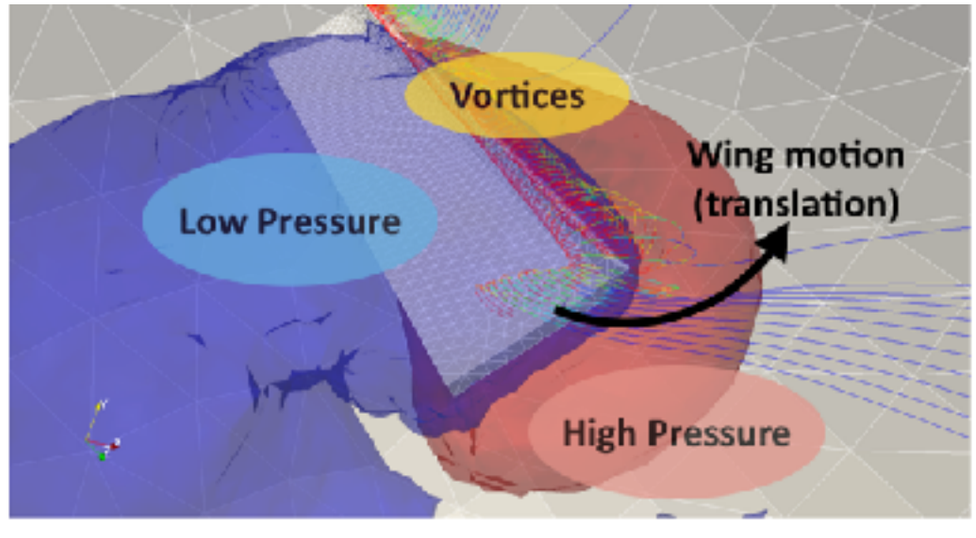



**(a) Modeling on kinematics (flapping, pitching, and lead-lag), geometrics (multi materials), and physicals**

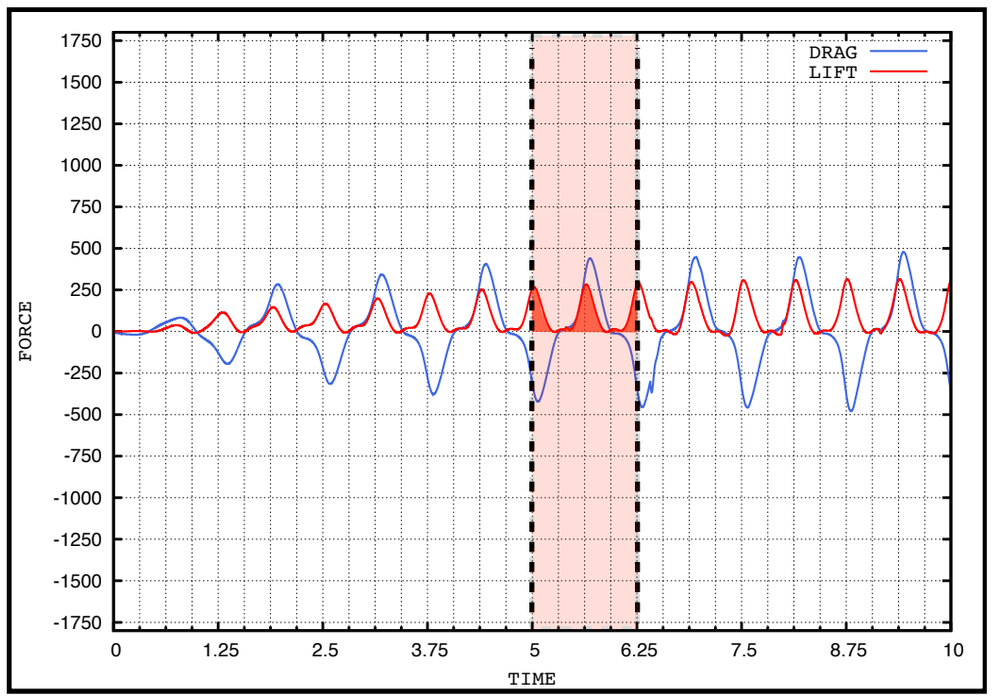



**(b) Mesh generation**

- Structure (quadratic tetrahedron)
243,243 nodes, 154,080 elements
- Fluid (linear tetrahedron)
68,348 nodes, 404,159 elements




**(c) Calculation and evaluation (visualization and data analysis)**




## ISSUE ON PARALLEL COMPUTING

- Is it possible to implement the communication using less processes?
- Can MPI_Spawn be a successful option?