Development of A Mid-Fidelity Aerodynamic Analysis Code for eVTOL Aircrafts

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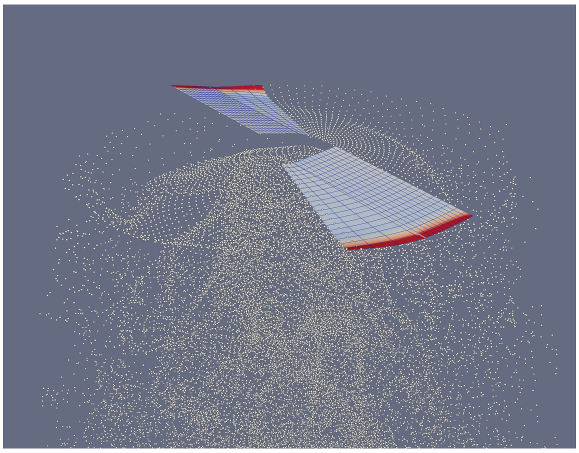
Abstract:

The eVTOL(electric Vertical Take-Off and Landing) has been a main concept for UAM(Urban Air Mobility) vehicles as it does not require any runways and it could hover in the airspace. That concept adopts multiple rotor system distributed on the airframe to generate sufficient lift forces while reducing the noise level from the rotors. However, in terms of the vehicle design, the rotor system makes the design difficult as it generates very complex aerodynamic interactions between the rotors and the rotor and the airframe, and the aerodynamic analysis is hard. A high-fidelity analysis such as CFD(Computational Fluid Dynamics) is a typical way for the aerodynamics, but it takes very long time which is unappropriate for the vehicle design. On the other hands, a low-fidelity method such as a panel method is incomparably faster than the high-fidelity method, but it does not take into account for non-linear aerodynamic effects such as separation. Thus, a mid-fidelity method taking low computation costs while having reasonable accuracy for the design should be developed.

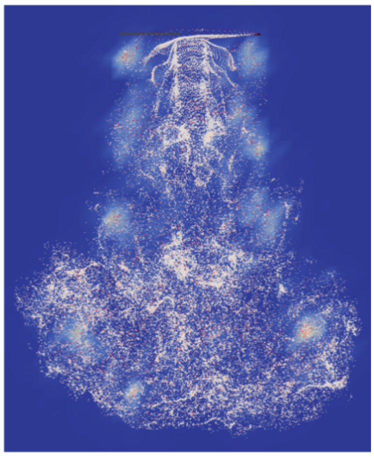
The research objective of this study is to develop a new mid-fidelity aerodynamic analysis code named FA3(Fast Aerodynamic Analysis for Aircrafts). It is based on the vortex methods that the airframe aerodynamics and the rotor aerodynamics are predicted by a panel method and NVLM(Nonlinear Vortex Lattice Method), respectively. NVLM incorporates a table look-up procedure in order to take into account for the non-linear aerodynamic effects around the rotors. The wake flows shed from the rotors are modelled by VPM. In that case, the computation costs increase exponentially by increasing the number of particles, but it is solved by adopting two acceleration methods of FMM(Fast Multipole Method) and VIC(Vortex-In-Cell) method into the code. For the better performance, the VIC method incorporates GPU computing with CUDA.

FA3 is validated in several rotor cases. As the first case, single UAV rotor with very low Reynolds number flows is considered, and the FA3 showed almost 50 times faster than CFD whereas the accuracy is comparable with CFD. As the second, a helicopter is considered to show that FA3 could compute the aerodynamics in full-configuration cases. The final case covers multiple rotors with a UAV-scaled airframe to validate that the computation costs could be still cheaper in multiple rotors cases. Currently, FA3 is being validated in the second and third cases, and the results would be included in the final manuscript.

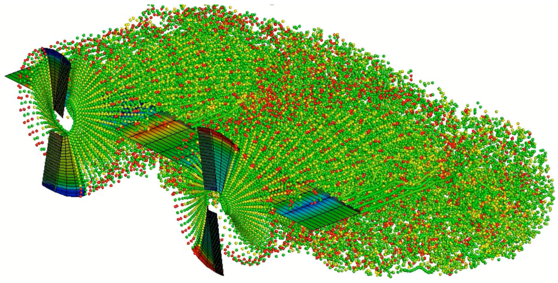
In this study, a new mid-fidelity aerodynamic analysis code was developed and validated in several rotor cases. This study showed the validity of FA3 for the aerodynamic analysis in UAM, even though it was not validated in any real UAM vehicle cases without comparable data. it is expected that the design process would be faster when using this code, correspondingly adopts the field of UAM more quickly.



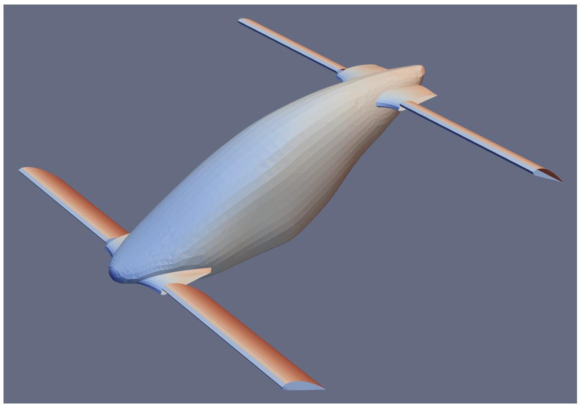
(a) Validation case 1: Single rotor



(b) Vorticity field computed by VIC method



(c) Validation case 2: Multiple Rotors



(d) Validation case 4: Full-configuration of UAM