Developing an Efficient Algorithm for Measuring Density in Axisymmetric Airflows Based on Background Oriented Schlieren

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Background Oriented Schlieren (BOS) enables density measurements of objects that deflect light passing through a medium, given that the medium and object are transparent (eg. hot air flowing above a candle flame). The object under investigation is placed in-between a conventional camera and a background plane with a dot pattern, and light deflection is measured by the camera as displacements of dots on the background. This input is used to generate a 2-D image of the object's density. Applications include viewing the densities of controlled flames and wind tunnel airflows without expensive or intrusive sensors, such as thermal imaging cameras and pressurometers. For axially symmetrical objects, a combination of integral transforms are normally used, namely the Fourier-Hankel and inverse Abel transforms. In this work, a new algorithm was designed to calculate density using simple matrix calculations. Two physical BOS setups were designed. The first used a telecentric camera and a large wooden apparatus. This setup was optimised to improve image resolution and measurement sensitivity, and mitigate mediator variables. The second setup used only a smartphone camera, and was further optimised. Several mathematical models were developed experimentally to relate image displacement to density, and the accuracy of these models was tested. These were implemented in several software algorithm prototypes that automatically detected and calculated airflow density. The speed, output resolution and level of automation was optimised for the final algorithm, resulting in a program that produced density images at speeds approaching real-time, at a high resolution, and with good quantitative accuracy.

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