# HFITS: Heat Flux Measurements using Infrared Thermography and a Plate Sensor

*Software Manual (Version 0.1)*

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# Summary

HFITS [1] is a software tool intended to support experiment measurements of heat flux over planar surfaces using infrared thermography. This technique enables spatially and temporally resolved heat flux measurements at a greater resolution than arrays of traditional point sensors. The target audience is researchers and engineers in thermal engineering disciplines. Developed in Python with a graphical front end, the software is accessible both to advanced users as well as to users with a more fundamental knowledge of complex thermogram manipulation and heat transfer analysis methods. HFITS consists of two main components: pre-processing of infrared thermograms (obtained from heat transfer experiments), and inverse heat transfer analysis (to deduce heat flux over the planar surface in those experiments). The software offers comprehensive functionalities, including support for custom thermogram formats, metadata handling, a graphical interface for selection of regions of interest, the ability to import additional temperature measurements to enhance convective heat transfer estimates, and the exporting of both computed field data and contour videos.

This manual details the prerequisites, underlying mathematical models, and operation of HFITS. At the time of writing the manual is in a developmental stage. In this 0.1 version of the manual, the authors outline the dependencies and basic operational instructions to run HFITS on a thermogram dataset.

# 1 Software Overview

The intended use of HFITS is to calculate the heat flux to a planar surface over time from sequential thermograms recorded with an IR camera in heat transfer experiments. The user should export the sequence of recorded thermograms to CSV files. HFITS then employs a two-step process for calculating heat flux to the surface:

1. Thermogram pre-processing (to rectify and crop thermograms to the region of interest).
2. Inverse heat transfer analysis (calculate heat flux over the region of interest).

To begin, ensure that the following software and dependencies are installed on the host system. Python packages may be installed by typing '`pip install <package>`' in a terminal.

1. Python 3.6+ and a terminal environment (we suggest running HFITS with VSCode).
2. Dependencies:
   - `opencv-python`
   - `ffmpeg-python`
   - `numpy`
   - `pandas`
   - `matplotlib`
   - `scipy`
   - `tqdm`
   - `fdm`
   - `h5py`
   - `seaborn`

Next, organize the source data:

1. Clone the repository.
2. Create a root working directory (e.g., `IHT`).
3. Create subdirectories to organize data (e.g., `T_source`, `T_proc`, and `Q_proc`).
4. Copy CSV thermograms (exported from the IR camera software) into `T_source`.

Next, pre-process the thermograms:

1. Run `HFITS_GUI.py` (if it's not already running).
2. Select the first tab in the GUI, 'Image Processing'.
3. Select the source (`T_source`) and destination (`T_proc`) directories.
4. Adjust the default values in the configuration fields as needed.
5. Select a CSV thermogram from which the rectangular region of interest will be identified.
6. Select 'Run' to crop and rectify the thermogram sequence:
   - Select reference points on the sample thermogram (each of the four corners of the region of interest, and then the approximate middle of each edge of the region of interest).

- Examine the processed sample thermogram for accuracy. Either proceed with processing the entire sequence or cancel to return to the GUI and select a different thermogram or reference points.

Finally, perform inverse heat transfer analysis:

1. Run `HFITS_GUI.py` (if it's not already running).
2. Select the second tab in the GUI, 'Inverse Heat Transfer'.
3. Select the source (`T_proc`) and destination (`Q_proc`) directories.
4. Adjust the default values in the configuration fields as needed.
5. Select 'Run' next to 'Apply Inverse Model' to perform inverse heat transfer calculations.
6. Select 'Run' next to 'Export PNG' to create contour images of the computed heat flux field at each time instance.
7. Select 'Run' next to 'Export Video' to create a video of the entire sequence of computed heat flux fields.

# References

[1] Parham Dehghani and Matthew J. DiDomizio. HFITS: Heat Flux Measurements using Infrared Thermography and a Plate Sensor. [Code repository], Github. https://github.com/ulfsri/HFITS, 2024.