AM5630: Foundations of CFD

Assignment 2 Report

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I. The Problem Statement

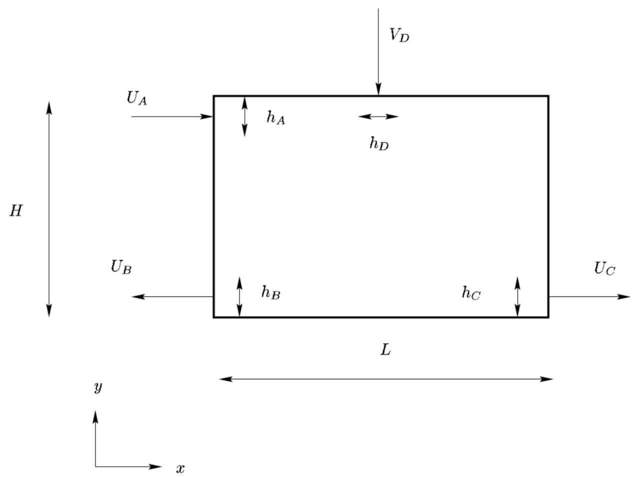


Figure 1: Computational domain. The extent in the third coordinate direction is 1. Physical data: $\rho = 1, k/c_p = 1/50, h_A/H = h_C/H = 0.068$. Boundary conditions: $U_A = 1, U_B = 0, U_C = 1, V_D = 0, T_A = 20^oC$. At $x = L$ (other than outlet), $T = 50^oC$

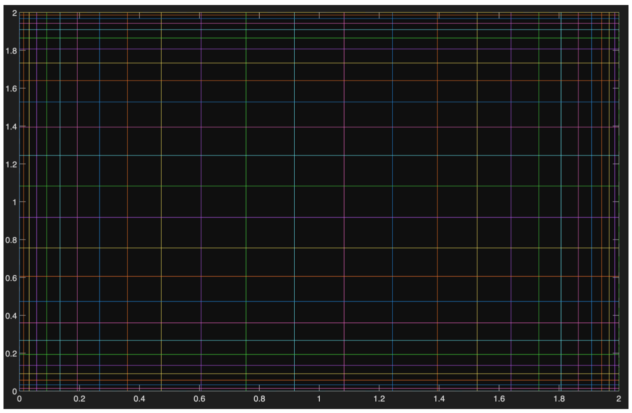
$$\frac{\partial}{\partial x}(\rho UT) + \frac{\partial}{\partial y}(\rho VT) = \frac{\partial}{\partial x}\left(\Gamma\frac{\partial T}{\partial x}\right) + \frac{\partial}{\partial y}\left(\Gamma\frac{\partial T}{\partial y}\right) + S \tag{1}$$

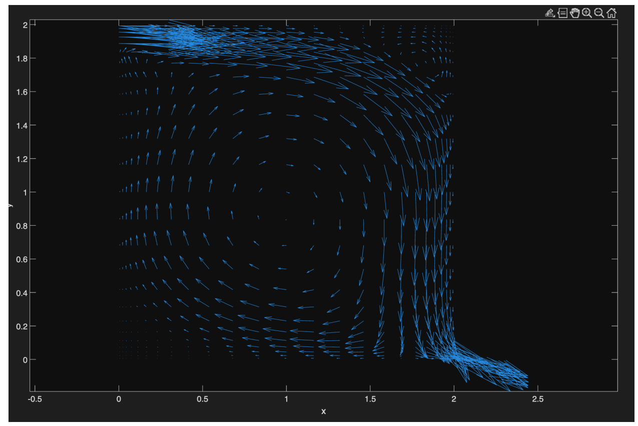
where, $\Gamma = k/c_p$. The algebraic equation system should be solved using TDMA (recommended) and Gauss-Seidel.

The goal of this assignment is to numerically solve the two-dimensional convection-diffusion (transport) equation for temperature using the Finite Volume Method (FVM). The problem builds upon the previous assignment on pure diffusion by introducing convective transport, which represents the advection of temperature by a given velocity field.

II. Given Data

Given is non-equidistant mesh and velocity profile's data.





To successfully solve the two-dimensional
convection-diffusion equation using the Finite Volume Method, the following steps are recommended:

Grid and Velocity Field

- Load the computational grid and the velocity field from the provided files.
- Use the supplied velocity.m file to plot the velocity field, which will help identify the inlet and outlet regions as well as the general flow pattern in the domain.

Program Development

- Begin implementing the FVM solver for the transport equation.
- Use a coarse grid during initial coding and debugging to reduce computational time and simplify troubleshooting. Once the solver works correctly, switch to a finer grid for improved accuracy.

Boundary Conditions

- When specifying a heat flux, divide the input by c_p (specific heat capacity) because the governing equation is in terms of temperature, not energy.
- If no boundary condition is given at a wall, apply a zero normal temperature gradient where eta is the coordinate normal to the wall.

Numerical Scheme

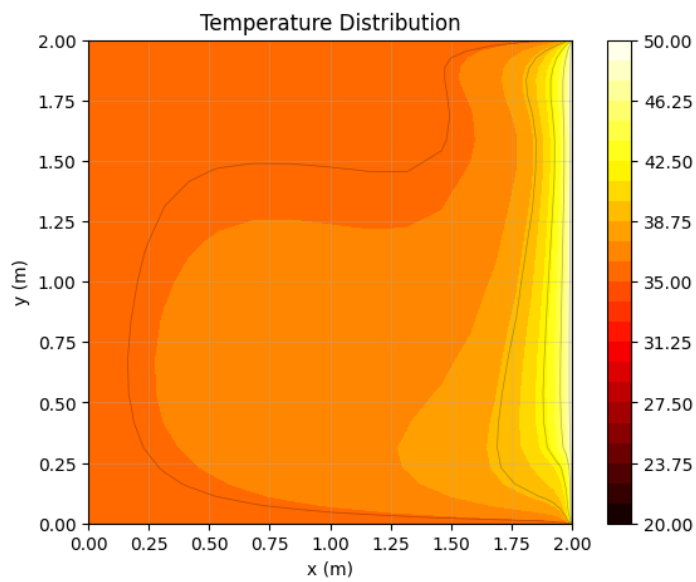
- Implement the hybrid differencing scheme for the convective terms to maintain stability and accuracy in regions with high convection.

Validation and Visualization

- Visualize intermediate results such as the temperature field and fluxes to verify correctness.
- Ensure continuity is satisfied in all control volumes to maintain mass conservation.

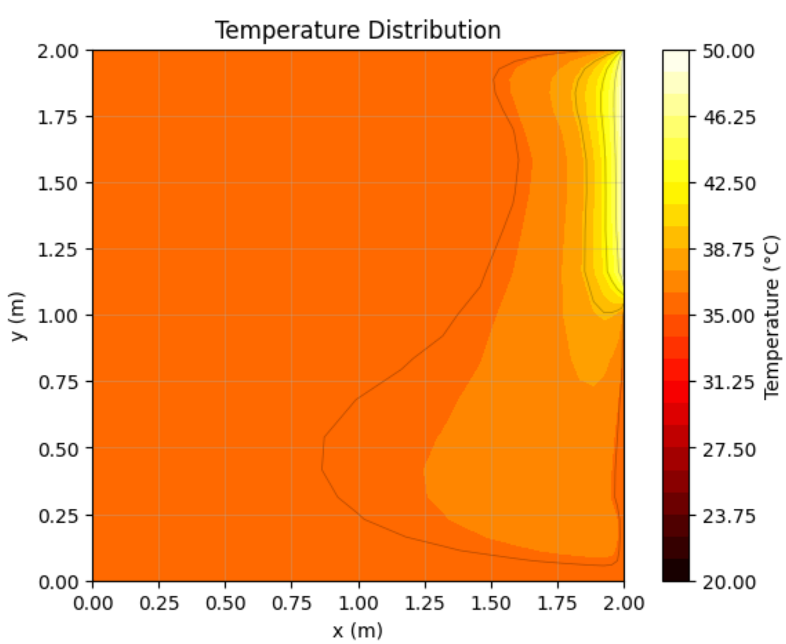
III. Result

For the default (given) Boundary conditions etc the plot comes out to be:

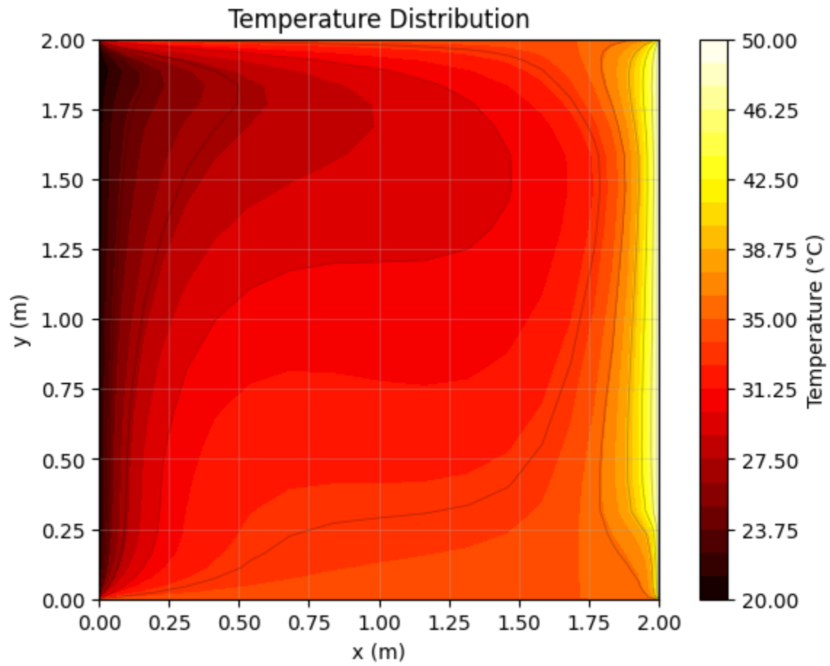


a. Making an interesting change of one boundary condition.

Changing the right wall heating so that only one half of the wall gets heated up



Heating the entire Left wall



b. Sensitivity to convergence