AE 625 - Particles Methods for Fluid Flow Simulation
Flow past circular cylinder with the RVM

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Using the Runge-Kutta integrator and the linear vortex panel method to simulate the flow past a circular cylinder of unit radius (R; D = 2R) centered at the origin at a Reynolds number ($Re = UD/\nu$) of 1000. Use the RVM for diffusion and use Chorin blobs.

The cylinder can be stationary with a constant free-stream. Choose γmax=0.1 and use anywhere between 25 to 75 panels for the body. Simulate this problem for a time of at least 3 seconds in total (ideally 4-5 seconds). Use a δt between 0.05 and 0.1 (0.1 is perfectly OK). Increase γmax if your code takes too long to run. Calculate the vortex momentum for the simulation.

Re = 1000 ; U = 1 m/s; D = 2 m; ν = UD/Re

The algorithm used for the following simulations:

- Solve Linear Vortex Panel Method for free stream.
- Introduce vortex particles to nullify slip over the panels.
- Convect the vortex particles in the stream using RK2 time integration.
- Check for penetration of vortex blobs with body and reflect them.
- Diffuse all vortex particles
- Check for penetration of vortex blobs with body and reflect them.

1 Plot tte vortices at each second (1, 2, ... 5), color the positive blobs differently from the negative ones.

Results:

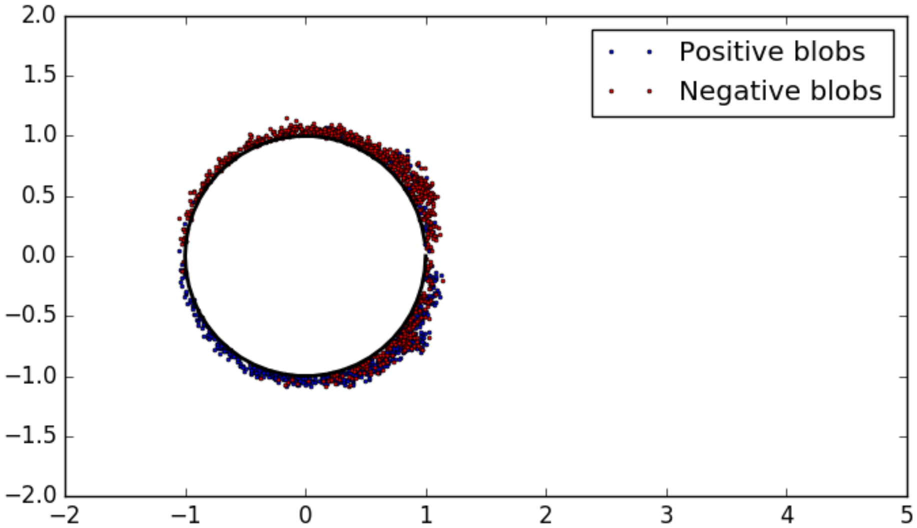
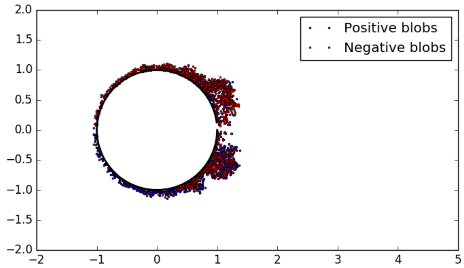
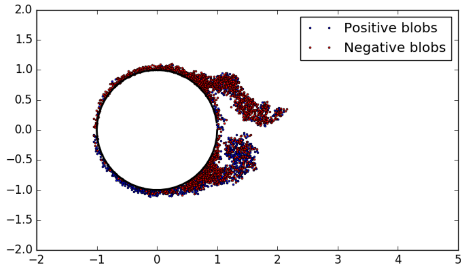


Figure 1: vortex particles after 1 sec

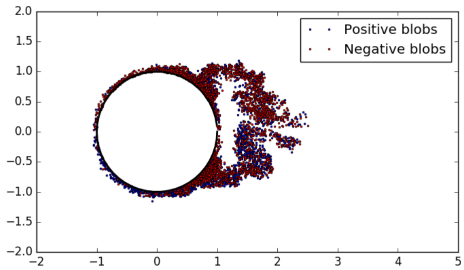


(a) vortex particles after 2 sec

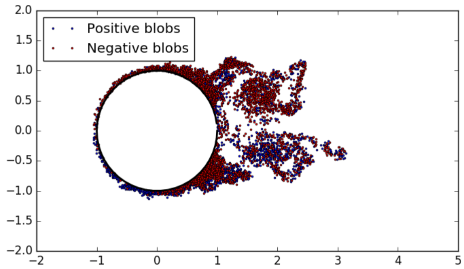


(b) vortex particles after 3 sec

Figure 2: vortex particles after 2 and 3 sec

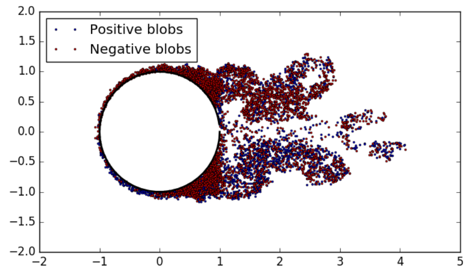


(a) vortex particles after 4 sec

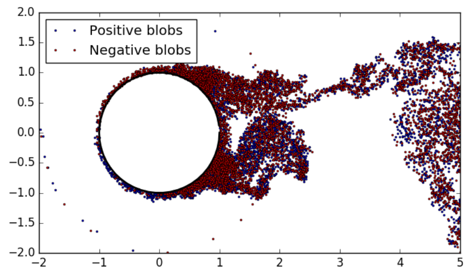


(b) vortex particles after 5 sec

Figure 3: vortex particles after 4 and 5 sec



(a) vortex particles after 7 sec



(b) vortex particles after 15 sec

Figure 4: vortex particles after 7 and 15 sec

2 Plot the velocity field around the cylinder at the final time (at least). Show the region (-2,-2) to (2,2) and also plot the region (0,0), (2,2) to show just the separated region.

Results:

The velocity field is as follows.
the following shows the separated region for t = 5 sec

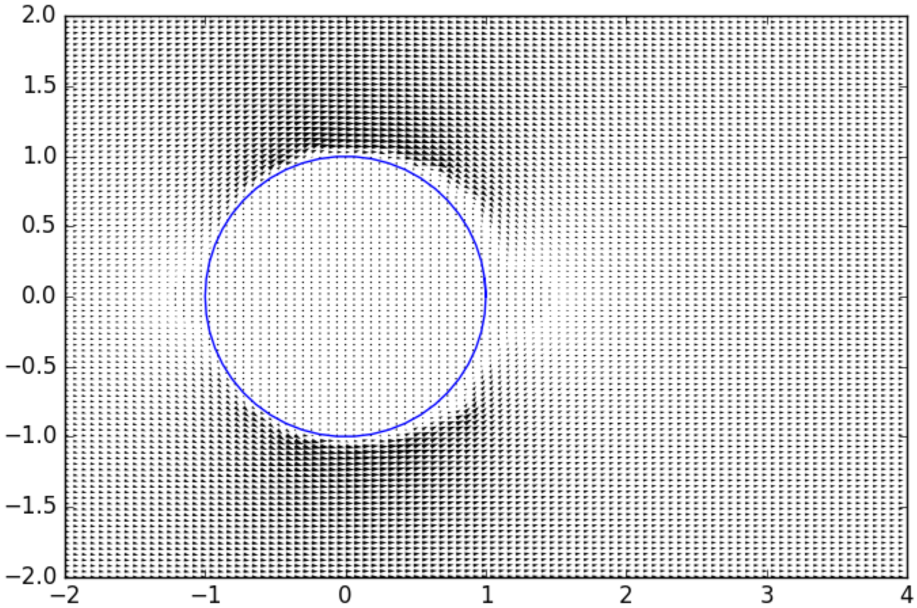
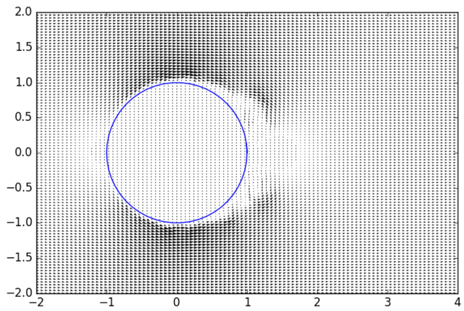
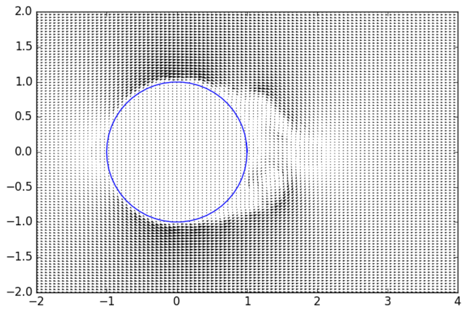


Figure 5: velocity field after 1 sec

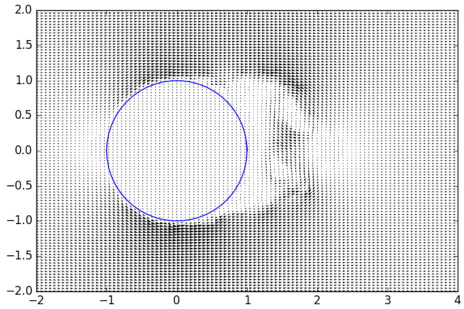


(a) velocity field after 2 sec

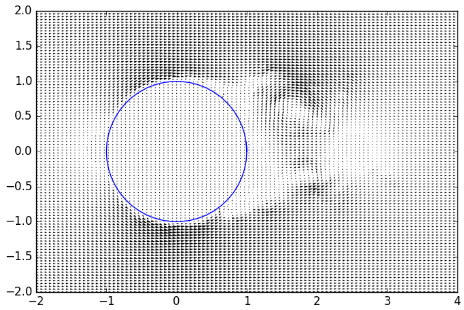


(b) velocity field after 3 sec

Figure 6: velocity field after 2 and 3 sec

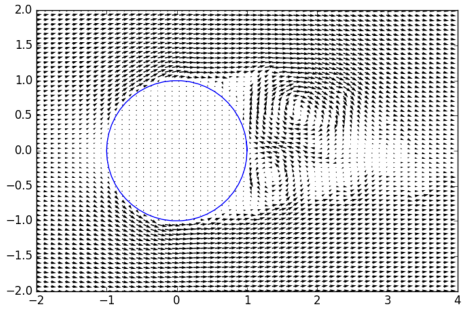


(a) velocity field after 4 sec

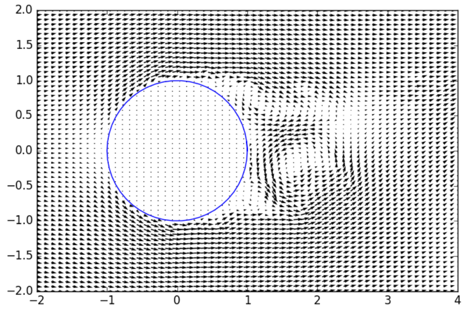


(b) velocity field after 5 sec

Figure 7: velocity field after 4 and 5 sec



(a) velocity field after 7 sec



(b) velocity field after 15 sec

Figure 8: velocity field after 7 and 15 sec

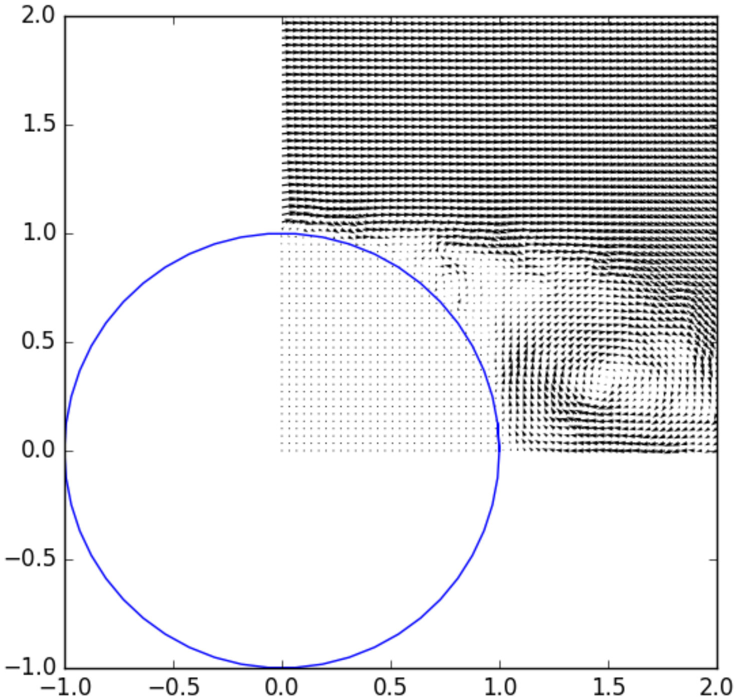


Figure 9: velocity field after 1 sec

3 Smooth the vortex momentum using running averages take the derivative and plot C_D vs time for the simulation.

Results:

C_d and C_l plots as follows.
C_d and C_l tend to ocscillate about 1 and 0 respectively for Re = 1000.

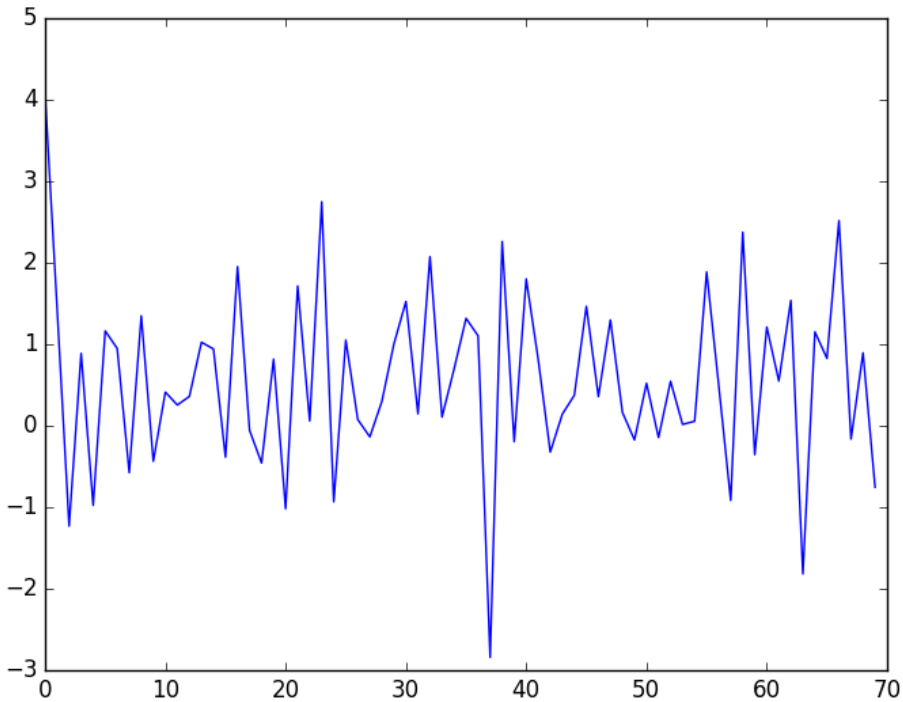


Figure 10: Cd caluclated with running average of vortex momentum.

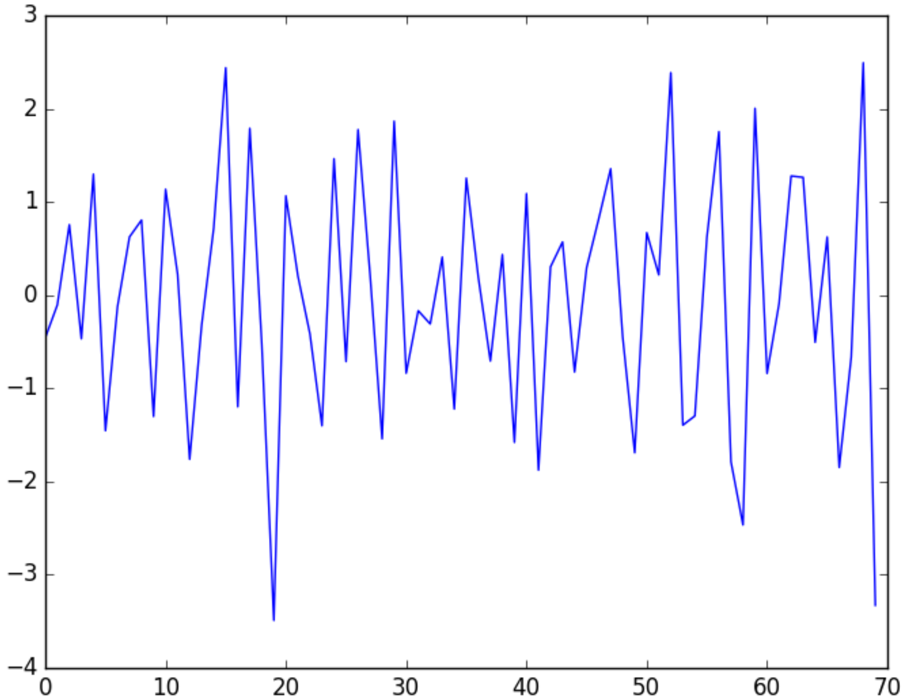


Figure 11: Cl caluclated with running average of vortex momentum.