

AE 625 -Particle Methods in Fluid Flow  
Simulation  
Assignment 10: Report  
PySPH - Lid Driven Cavity

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## 1 Introduction

Results for centreline velocity (u and v) in Lid Driven Cavity problem were obtained with the following combinations:

Four types of kernels have been used

-Cubic Spline

-Gaussian

-Quintic Spline

-Wendland Quintic

with hdx values varied as - 0.5, 1.0, 2.0

nx has been varied from - 25, 50,100

As a result, 36 combinations were formed, results for which are shown below.

The results are also compared with respect to Ghia et al.

$$Re = 100$$

## 2 Variation of Centreline velocity with change in kernel,nx and hdx

### 2.1 $hdx = 0.5$

#### 2.1.1 kernel = cubic spline

$nx = 25$

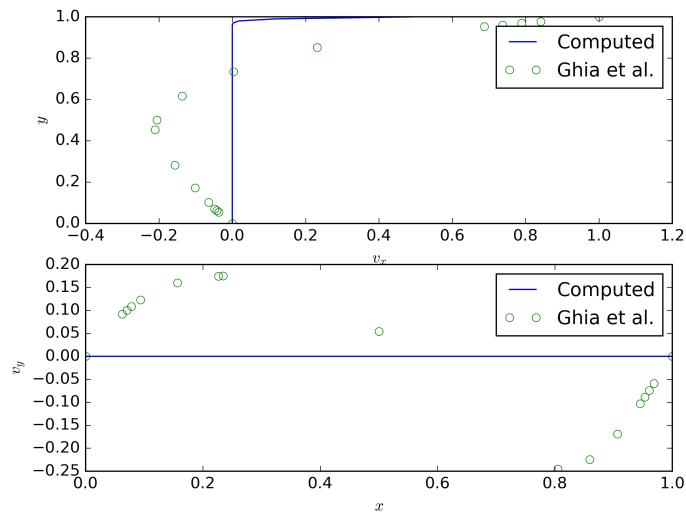


Figure 1: Centreline velocities (y vs. u and v vs. x)

$nx = 50$

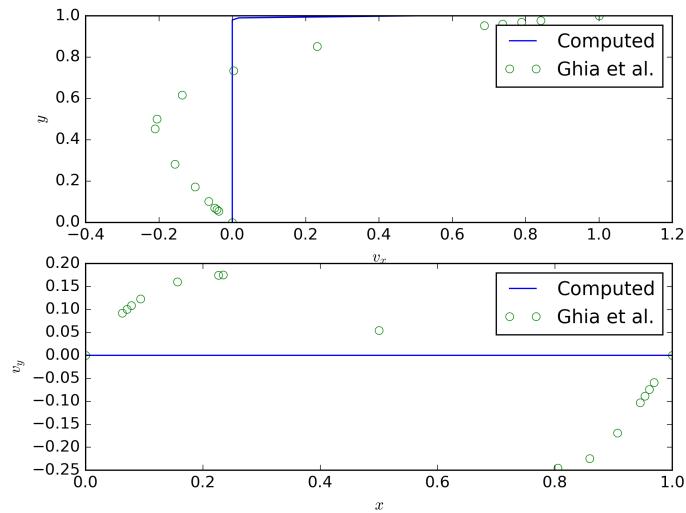


Figure 2: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

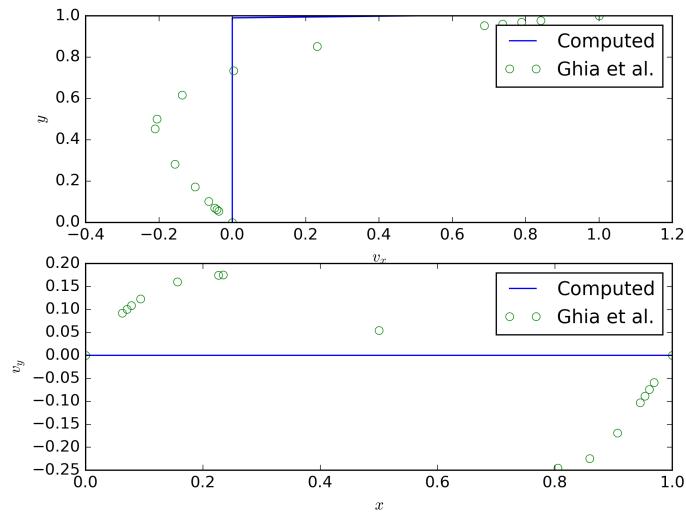


Figure 3: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.1.2 kernel = Quintic spline

$nx = 25$

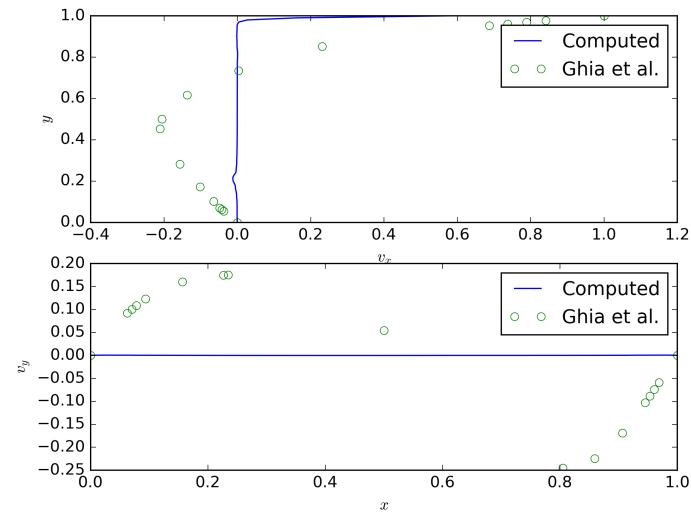


Figure 4: Centreline velocities (y vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

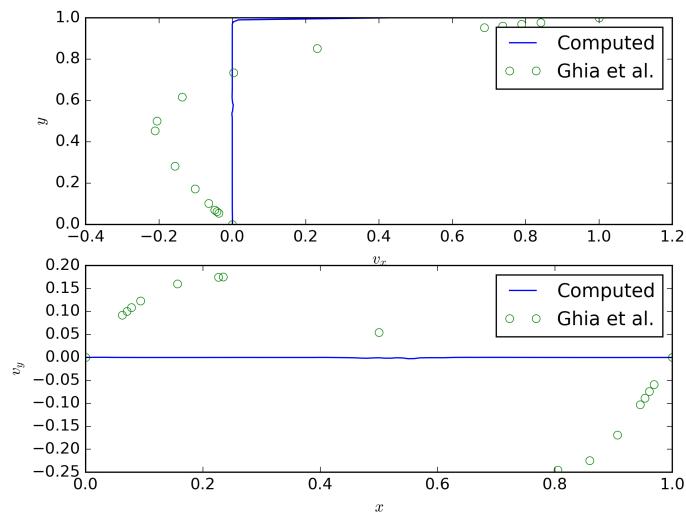


Figure 5: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

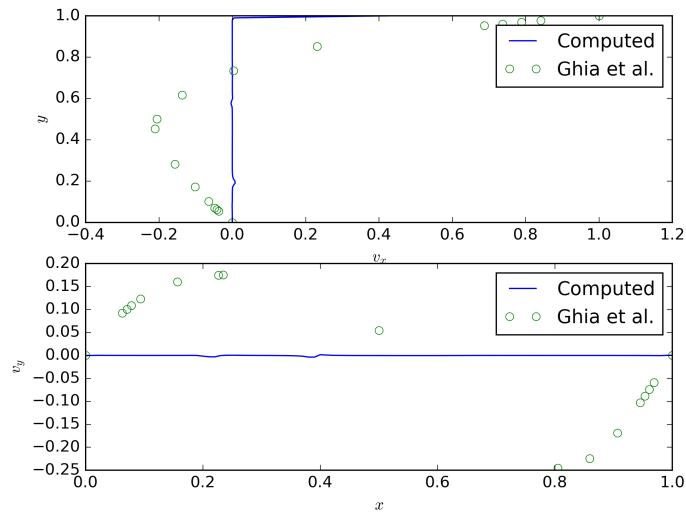


Figure 6: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.1.3 kernel = Gaussian spline

$nx = 25$

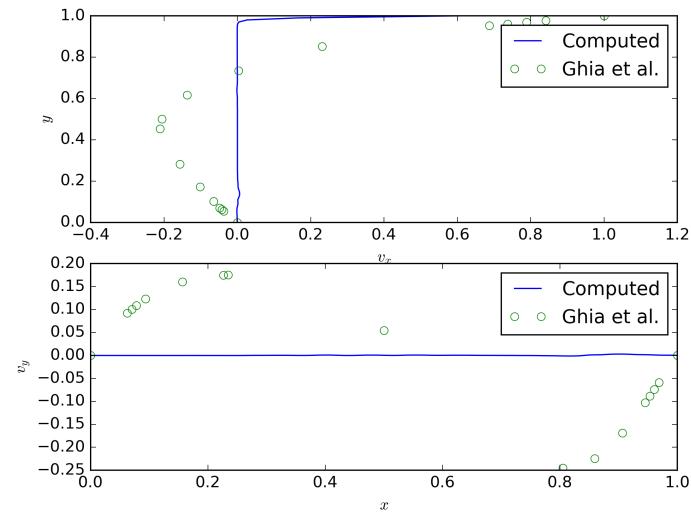


Figure 7: Centreline velocities (y vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

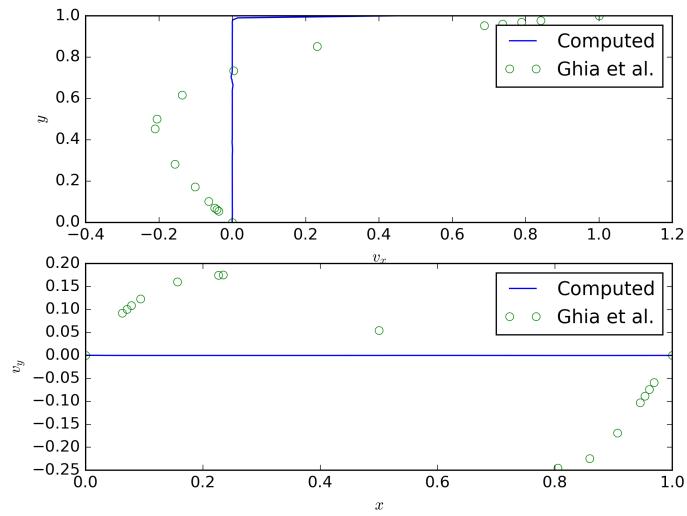


Figure 8: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

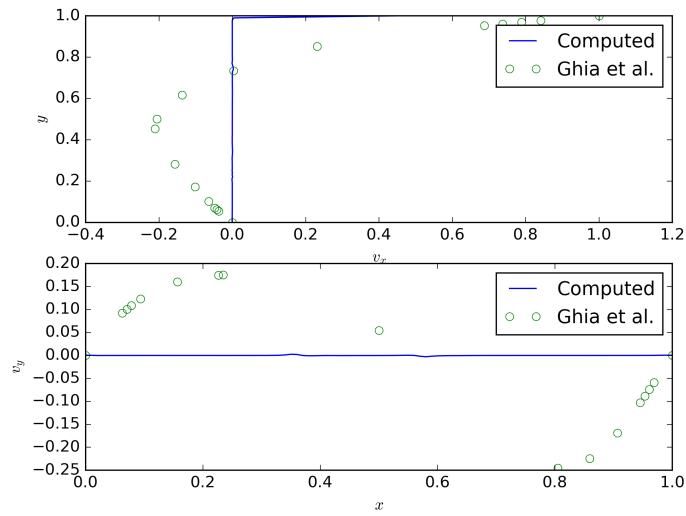


Figure 9: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

#### 2.1.4 kernel = Wendland Quintic spline

$nx = 25$

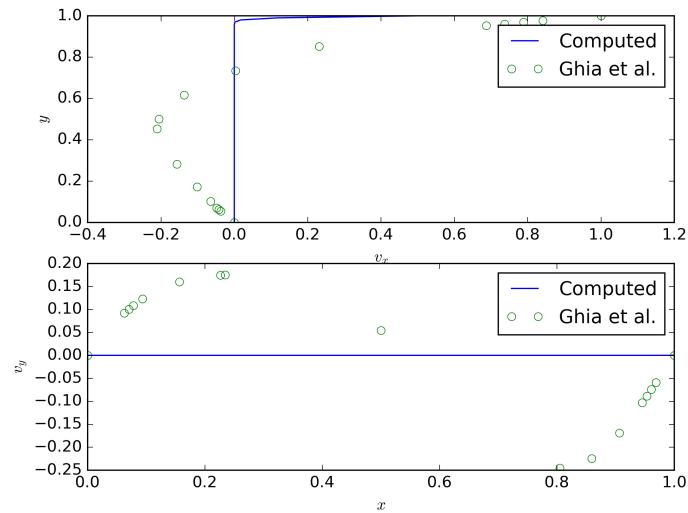


Figure 10: Centreline velocities (y vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

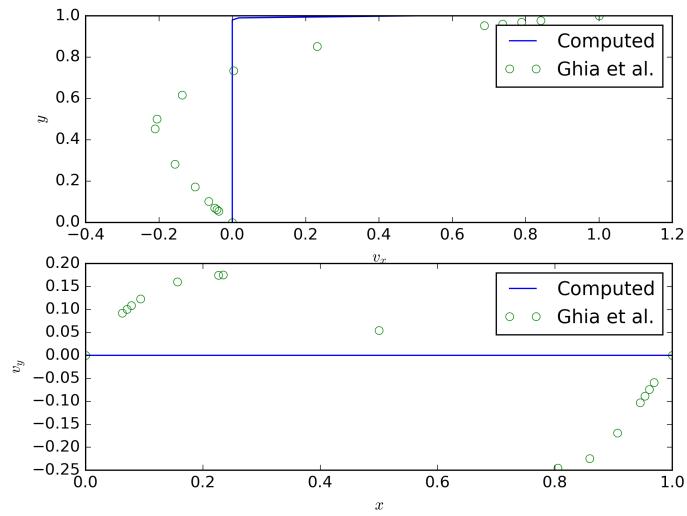


Figure 11: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

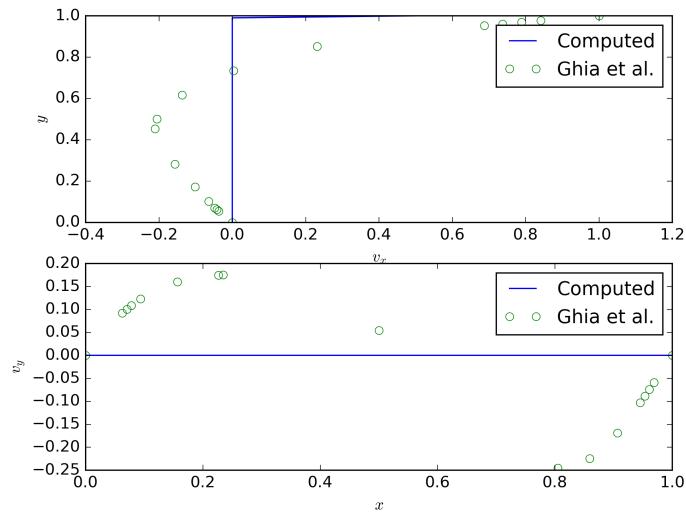


Figure 12: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

## 2.2 $\text{hdx} = 1.0$

### 2.2.1 kernel = cubic spline

$nx = 25$

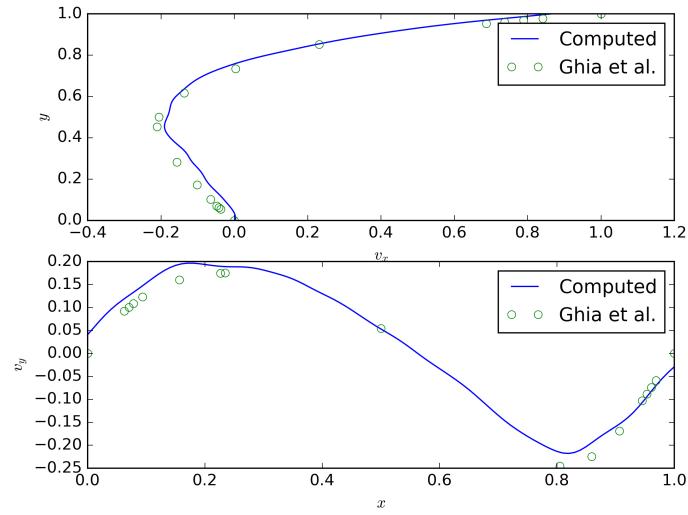


Figure 13: Centreline velocities (y vs. u and v vs. x)

$nx = 50$

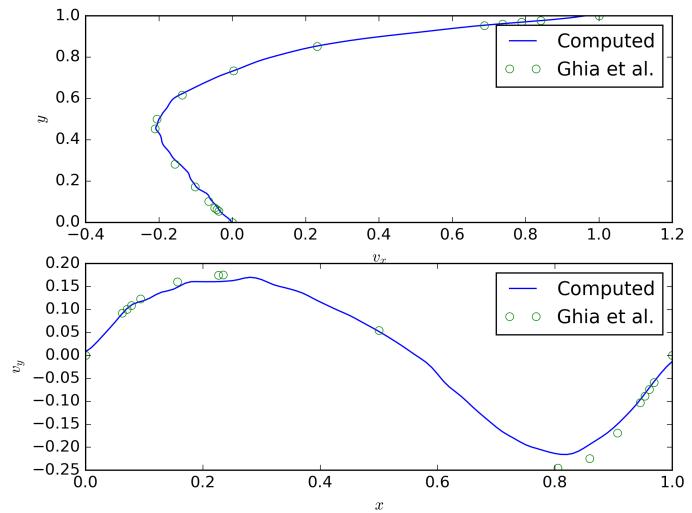


Figure 14: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

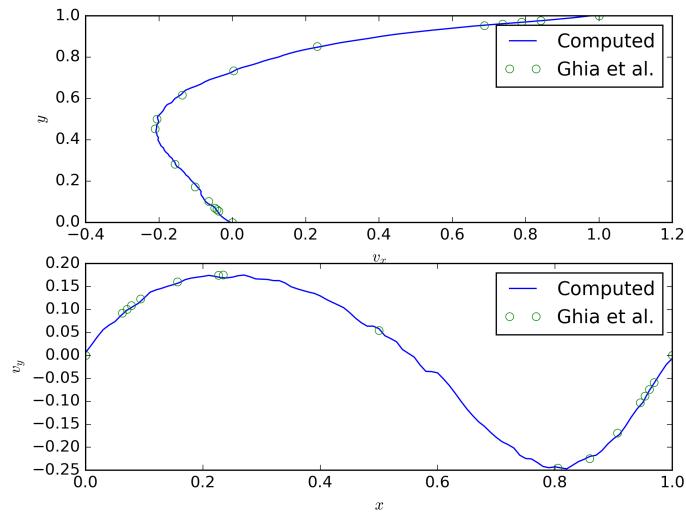


Figure 15: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.2.2 kernel = Quintic spline

$nx = 25$

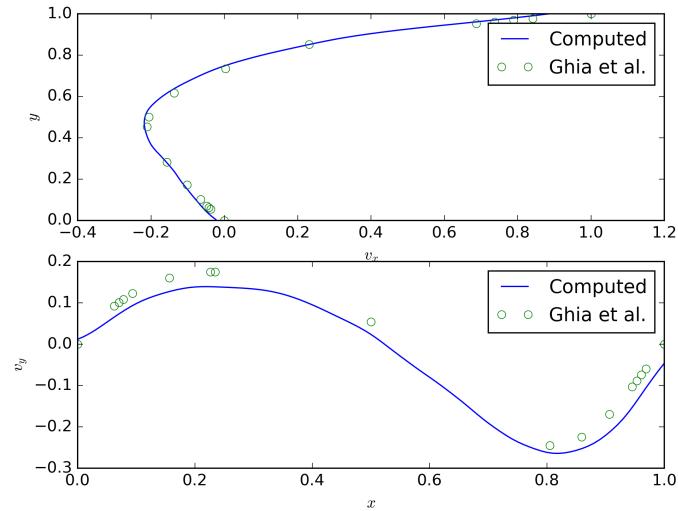


Figure 16: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

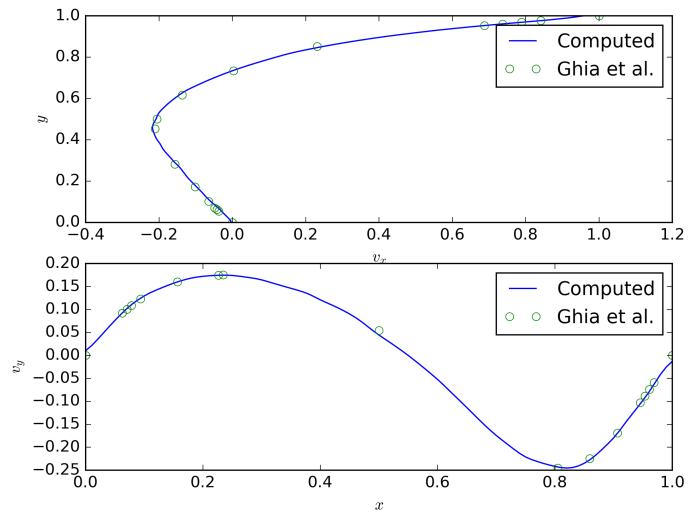


Figure 17: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

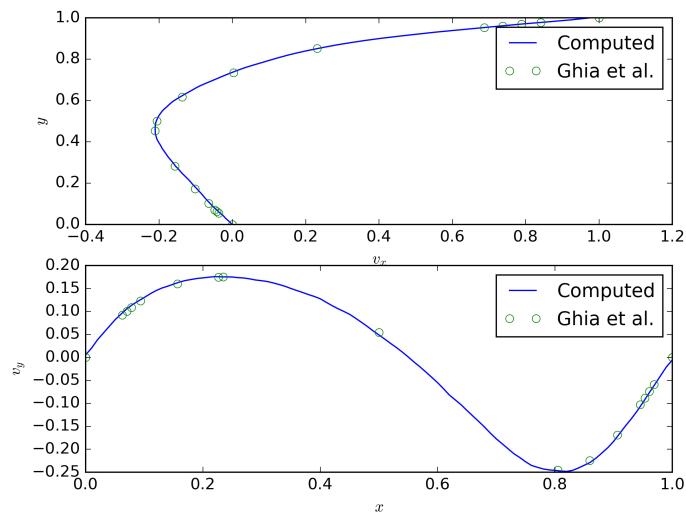


Figure 18: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.2.3 kernel = Gaussian spline

$nx = 25$

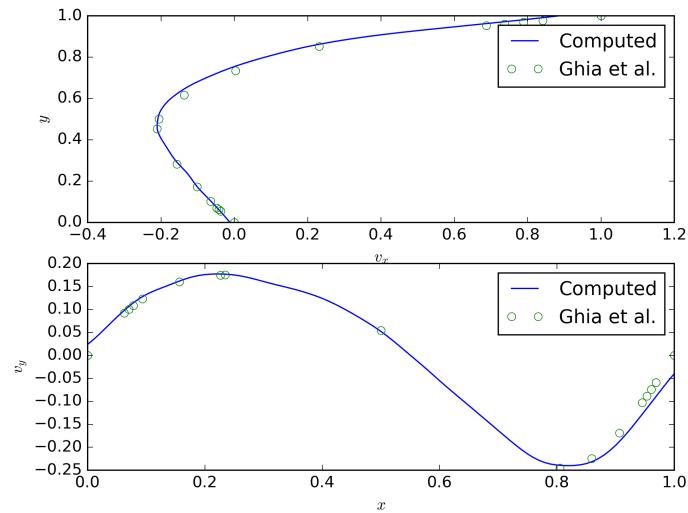


Figure 19: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

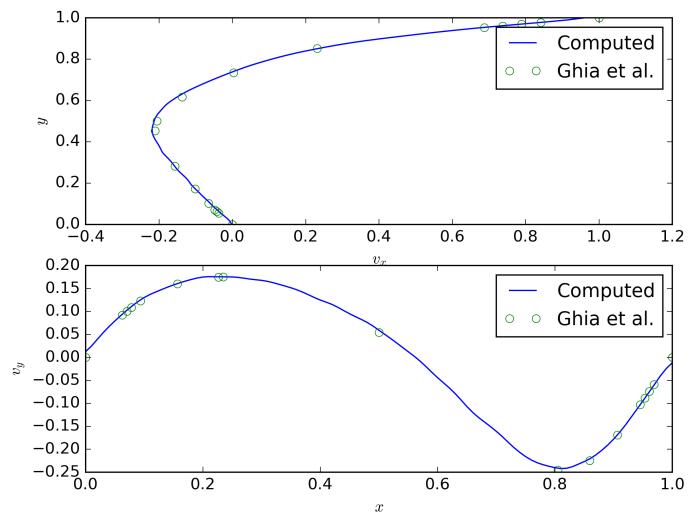


Figure 20: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

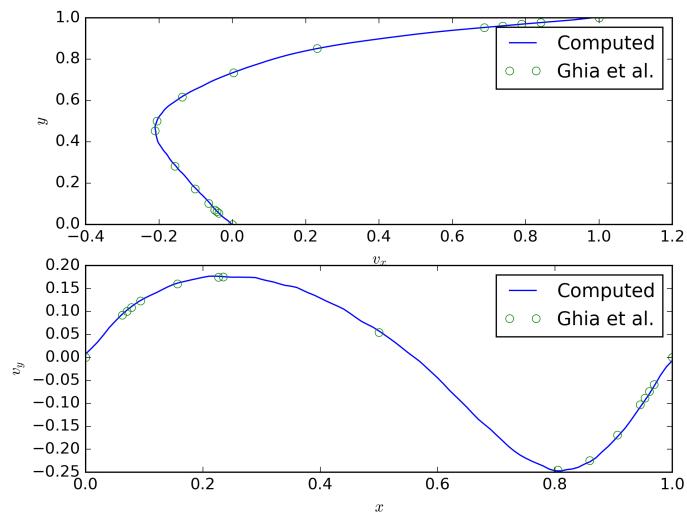


Figure 21: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

#### 2.2.4 kernel = Wendland Quintic spline

$nx = 25$

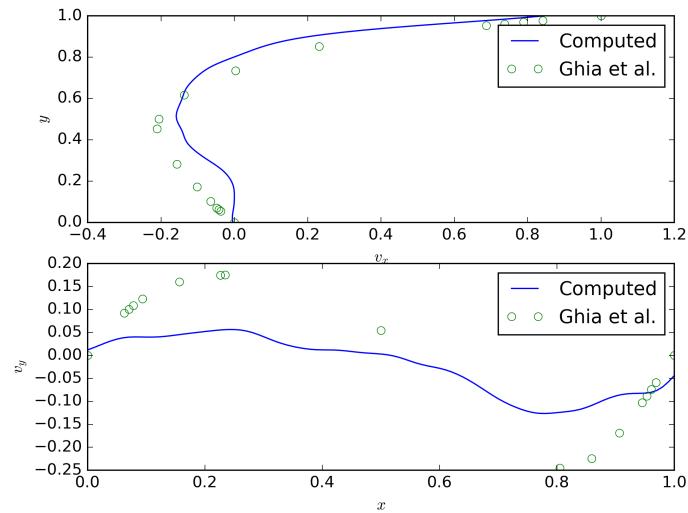


Figure 22: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

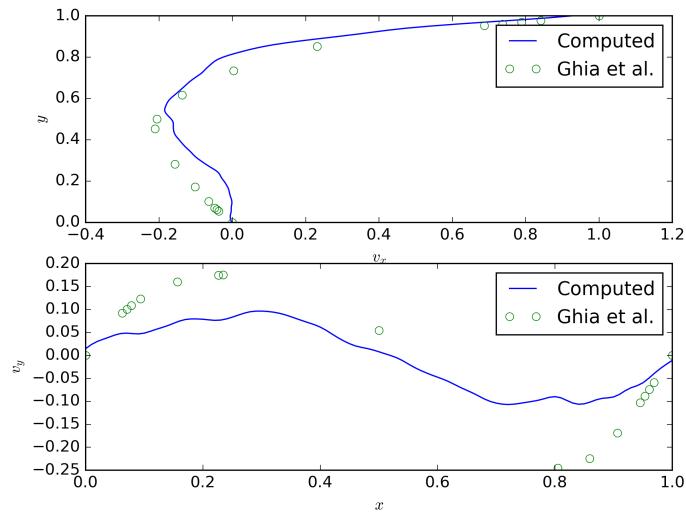


Figure 23: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$$nx = 100$$

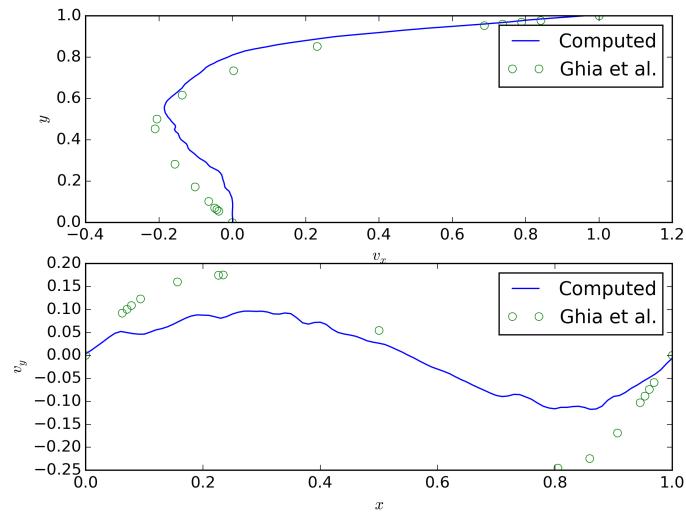


Figure 24: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

## 2.3 $hdx = 2.0$

### 2.3.1 kernel = Cubic spline

$nx = 25$

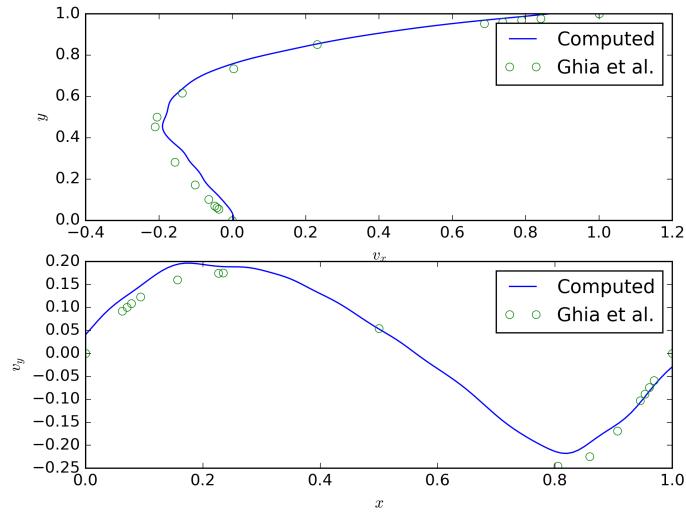


Figure 25: Centreline velocities (y vs. u and v vs. x)

$nx = 50$

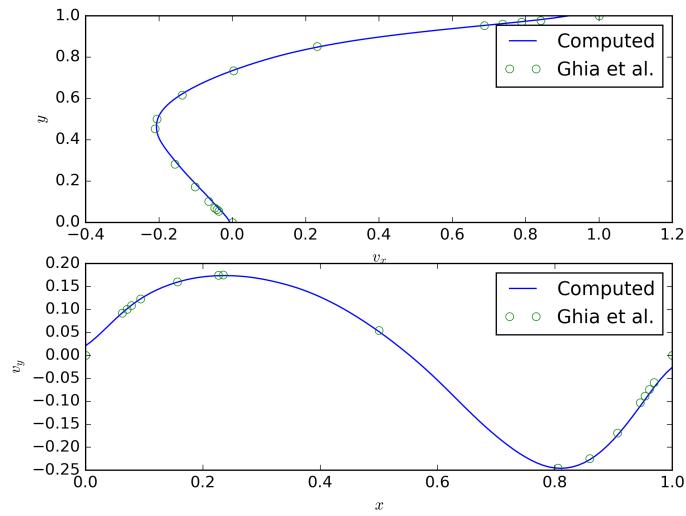


Figure 26: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

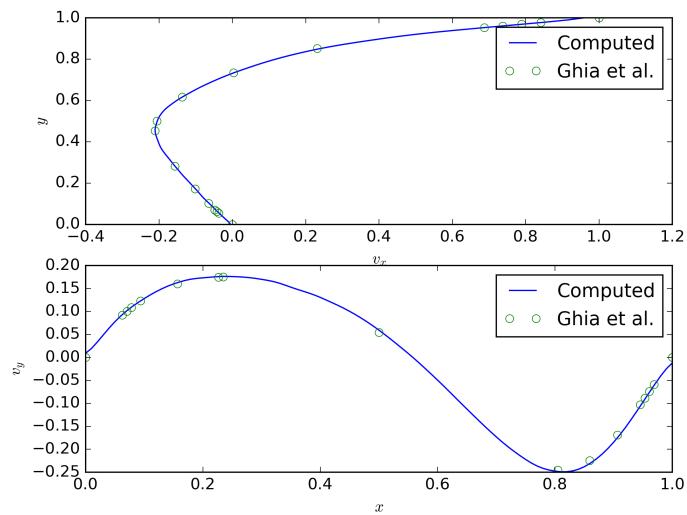


Figure 27: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.3.2 kernel = Quintic spline

$nx = 25$

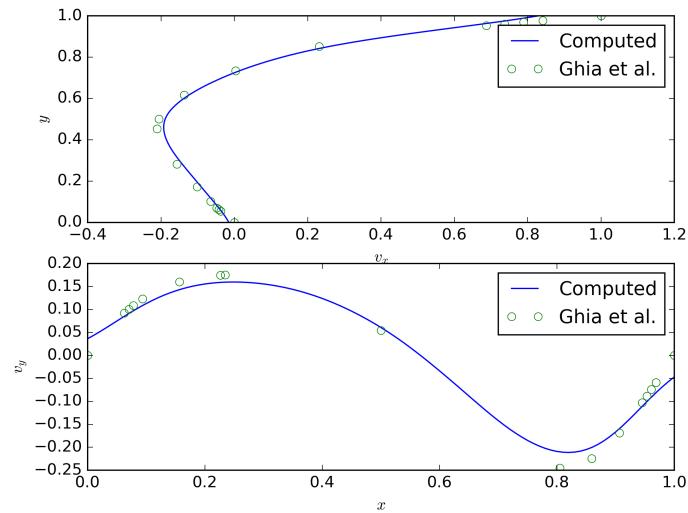


Figure 28: Centreline velocities (y vs. u and v vs. x)

$nx = 50$

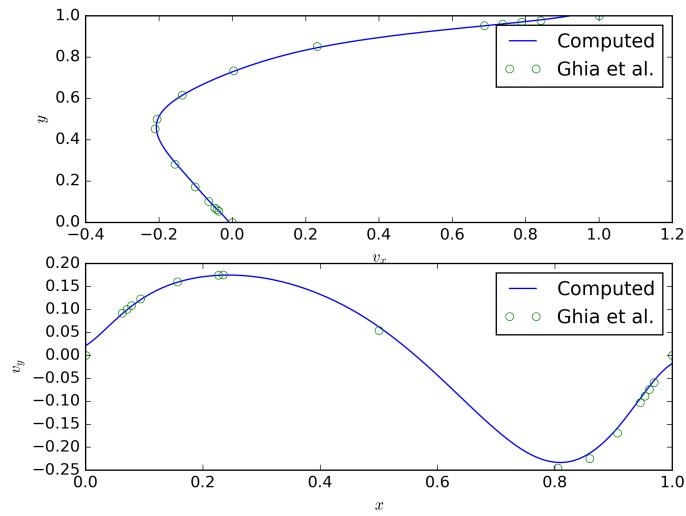


Figure 29: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

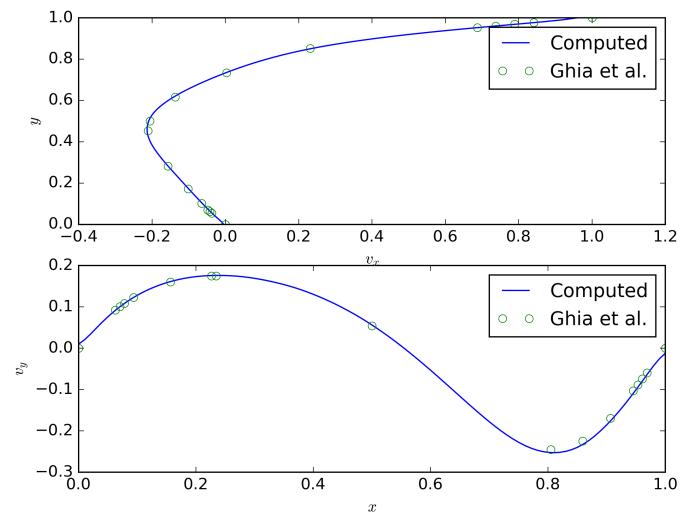


Figure 30: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.3.3 kernel = Gaussian spline

$nx = 25$

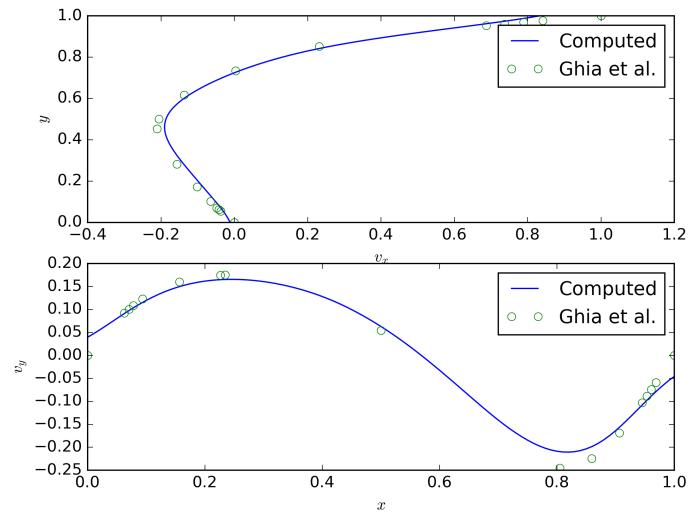


Figure 31: Centreline velocities (y vs. u and v vs. x)

$nx = 50$

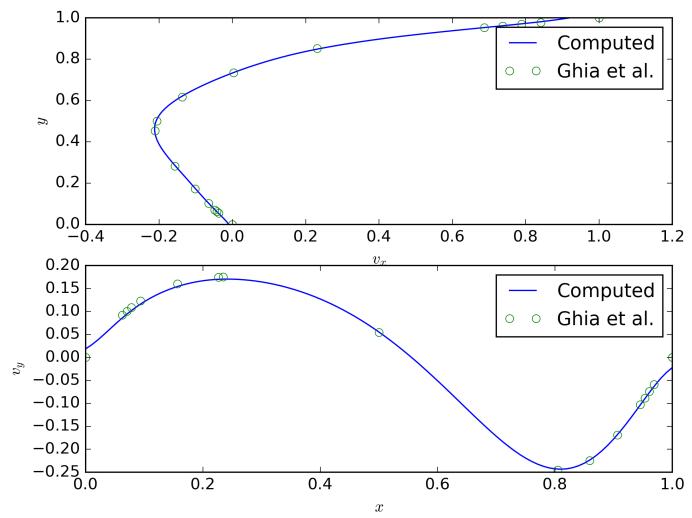


Figure 32: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

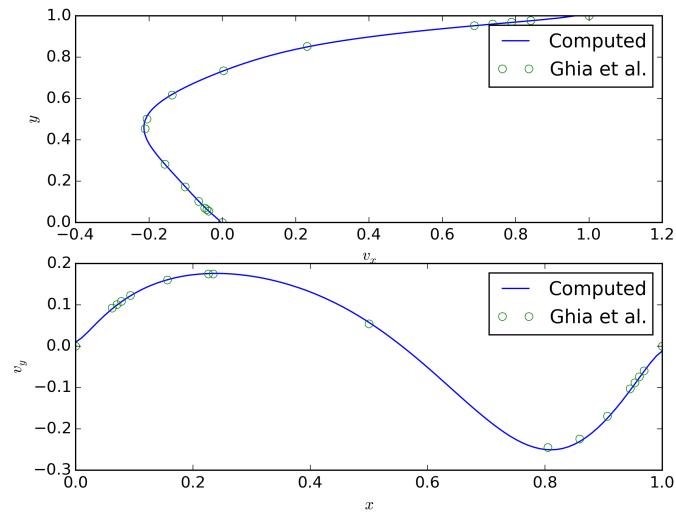


Figure 33: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 2.3.4 kernel = Wendland Quintic spline

$nx = 25$

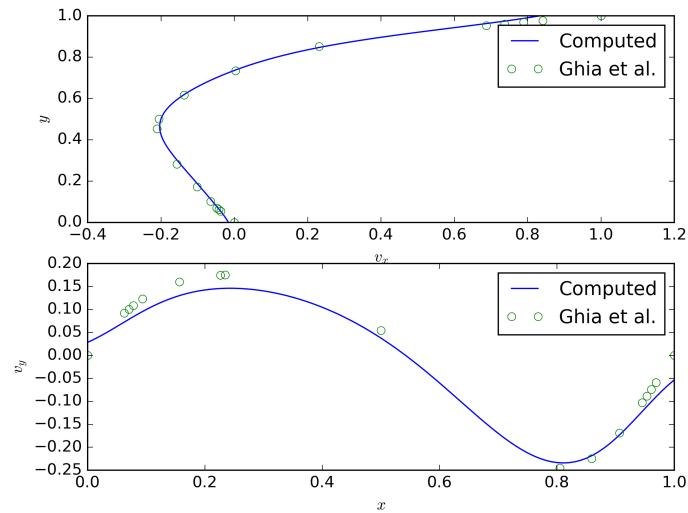


Figure 34: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 50$

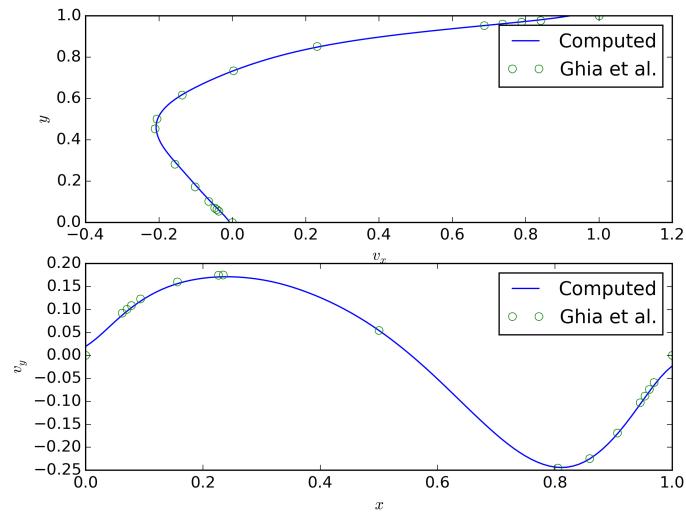


Figure 35: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

$nx = 100$

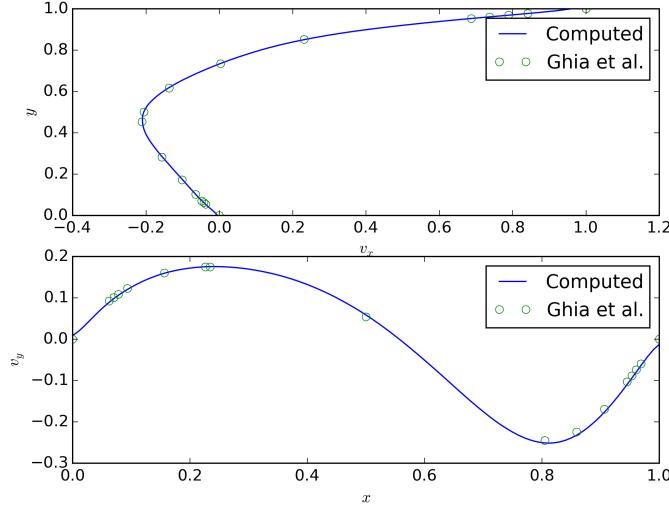


Figure 36: Centreline velocities ( $y$  vs.  $u$  and  $v$  vs.  $x$ )

### 3 Results and Discussion

- Run time decreases as  $hdx$  is increased for a particular kernel and  $nx$ .
- Run time increases as  $nx$  is increased for a particular kernel and  $hdx$ .
- For a particular  $hdx$  and  $nx$ , run time increases in the order - CubicSpline < QuinticSpline < WendlandQuinticSpline < Gaussian
- For  $hdx = 0.5$ , deviation of results from reference is much more pronounced than for  $hdx = 1.0$  and  $hdx = 2.0$ . This remains same for all  $hdx < 1.0$ .
- Smoothness of the plots obtained for computed centreline velocities increases (accuracy remaining almost same) when  $hdx$  is increases from 1.0 to 2.0 for cubic kernel.
- For Wendland Quinstic Spline, Accuracy is very less for  $hdx = 1.0$  as compared to  $hdx = 2.0$ .
- For Gaussian kernel, the accuracy and smoothness remains almost same for both  $hdx = 1.0$  and  $hdx = 2.0$ .
- As  $nx$  is increased from 25 –  $>$  50 –  $>$  100, error in the computed values of centreline velocities and the reference values decreases.