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A Comparison of Alternating Direction Swept Remap and Intersection Remap in the X-FEM Alegra Code

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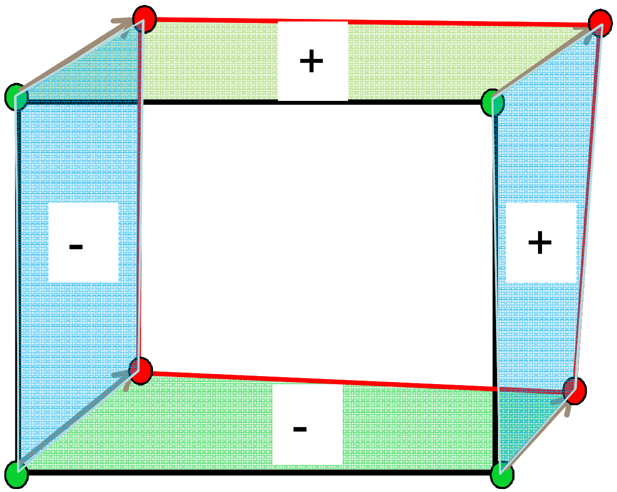
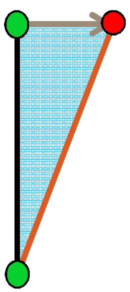
Talk Outline:

- Overview of swept remap
- Overview of intersection remap
- Differences between the two algorithms
- Comparison test problems
  - Translation at several mesh orientations
  - Expansion of a distribution
  - Translation and shear test
- Preliminary conclusions and future directions

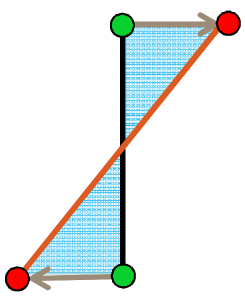
Alternating-Direction, Swept Remap

- Nodal velocities
- End-of-Lagrangian step element
- Next step element
- Fluxes = area swept by an element face
- x fluxes, y fluxes
- Flux order alternates xy, yx, xy, …
- Scalar flux description is simple, less descriptive
- 1D interpolation uses sweep's facial neighbors





1D interpolation ignores transverse 2nd and 3rd order variations in fluxed values

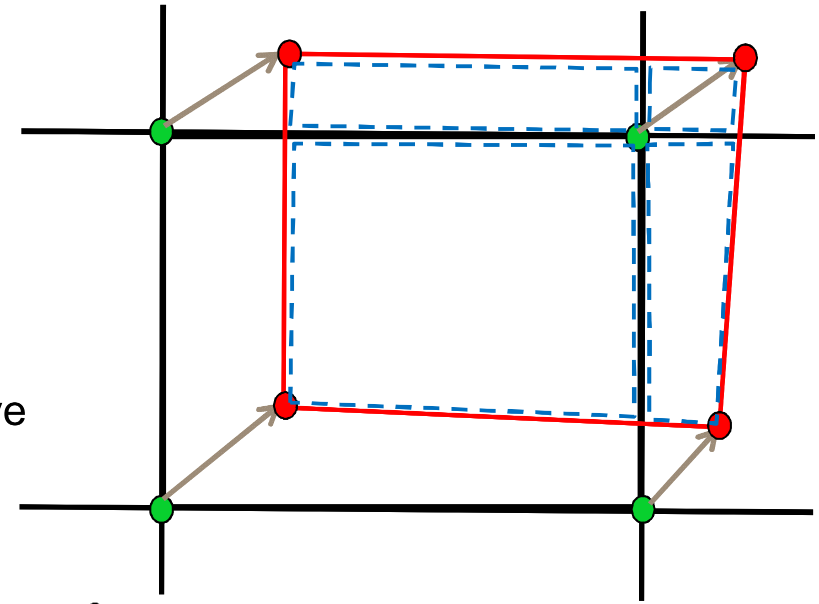


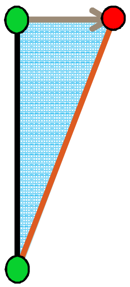
Scalar description misses finer detail of volume exchange

- Simpler algorithm that is computationally fast
- Due to two spatial sweeps, creating an intermediate state, higher dissipation

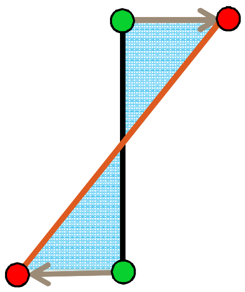
Intersection Remap

- Nodal velocities
- End-of-Lagrangian step element
- Next step element
- Fluxes = polygonal intersection meshes
- Flux polygons
- Single step
- polygonal flux description is more descriptive
- 2D interpolation uses all donor neighbors





2D interpolation includes transverse 2nd and 3rd order variations in fluxed values



polygonal description includes finer detail of volume exchange

- Complex algorithm that is computationally slower
- Due to single remap step dissipation is reduced for smooth flows
- Dissipation may be increased in areas of sharp discontinuity due to monotonic limiting

Translation Test Problem Description

- Gaussian densitv distribution

$$\rho = 20 \exp^{-10\left[(x_c - x_{disk})^2 + (y_c - y_{disk})^2\right]/r_{disk}}$$

- Nodal velocities are specified in input (no momentum fluxing is used)

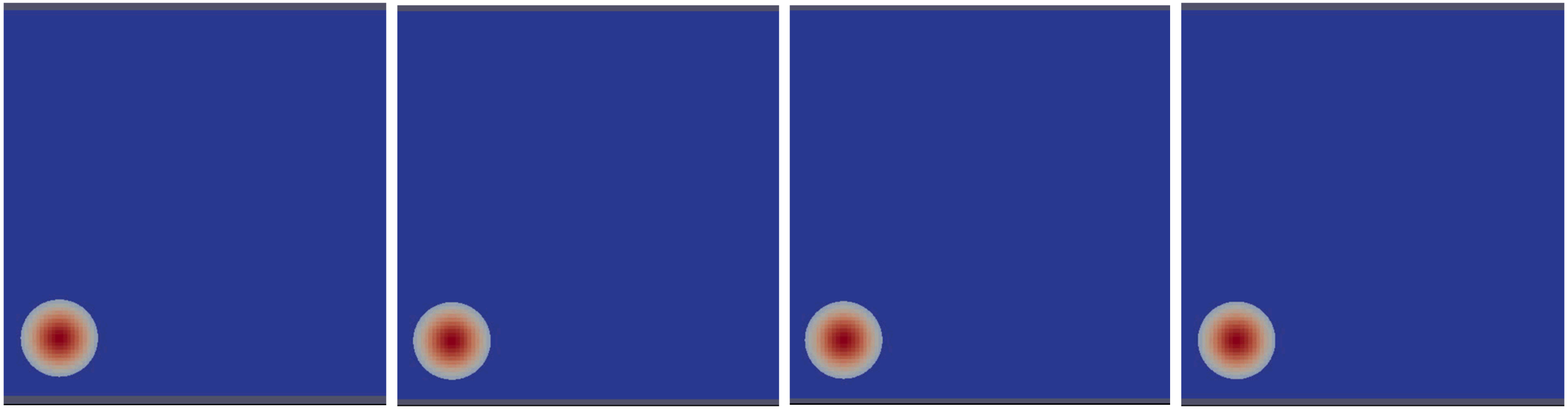
$$\vec{u} = u \cos\theta \hat{i} + v \sin\theta \hat{j}$$

where $$u = 1.0$$

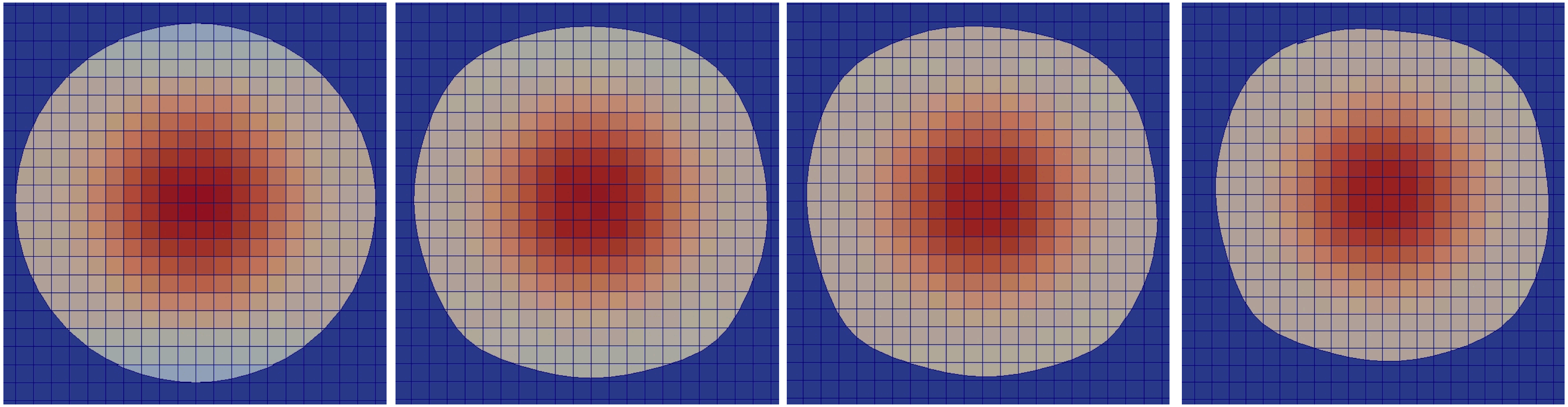
$$if\ (t > t_{mid}) u = -1.0$$

- Circle moves away from starting position and back
- Accuracy is measured by L1 error of each element $L_1 Error = \sum_{ncells} Vol_{element}(\rho_{end} - \rho_{start})$
- Error compares the starting element density in each element with the problem's ending material density
- Second order interpolation is used for both swept and intersection remaps
- Fixed time step for all angles: maximum Courant number 0.4

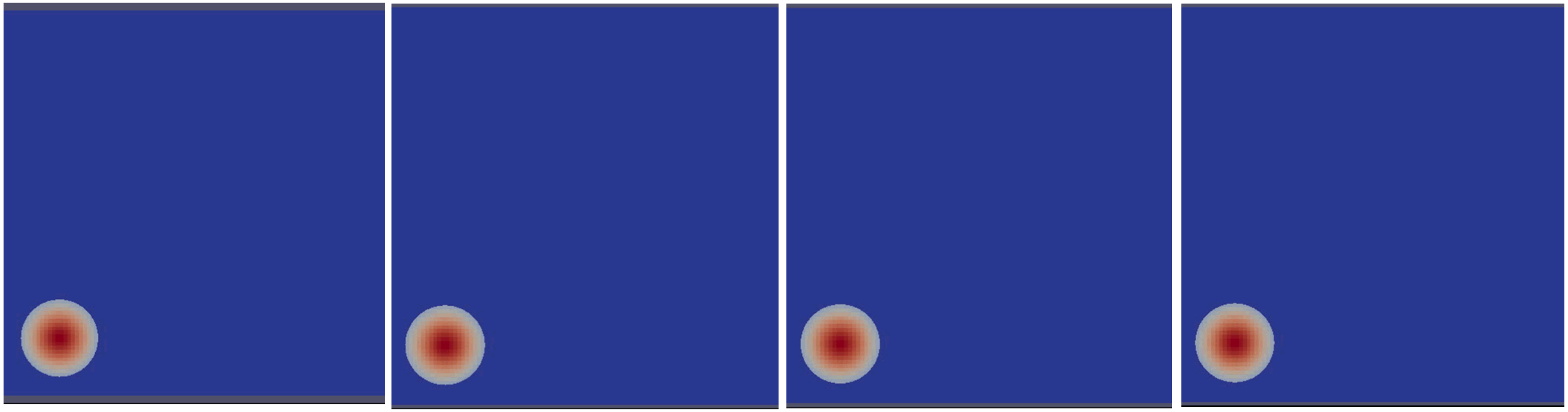
Swept Translation Test Problem



0 degrees 15 degrees 30 degrees 45 degrees

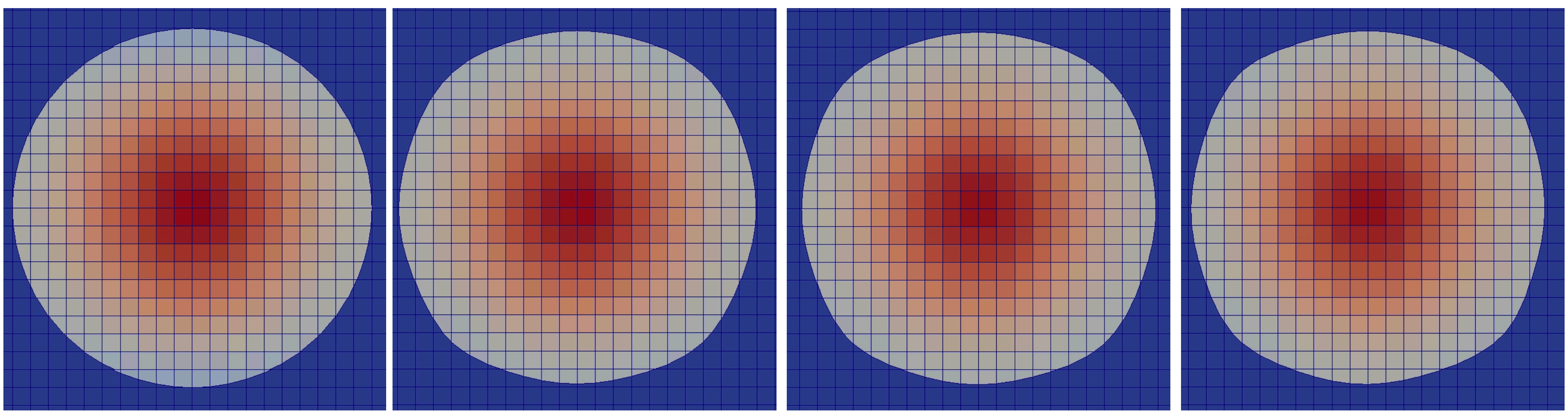


Intersection Translation Test Problem



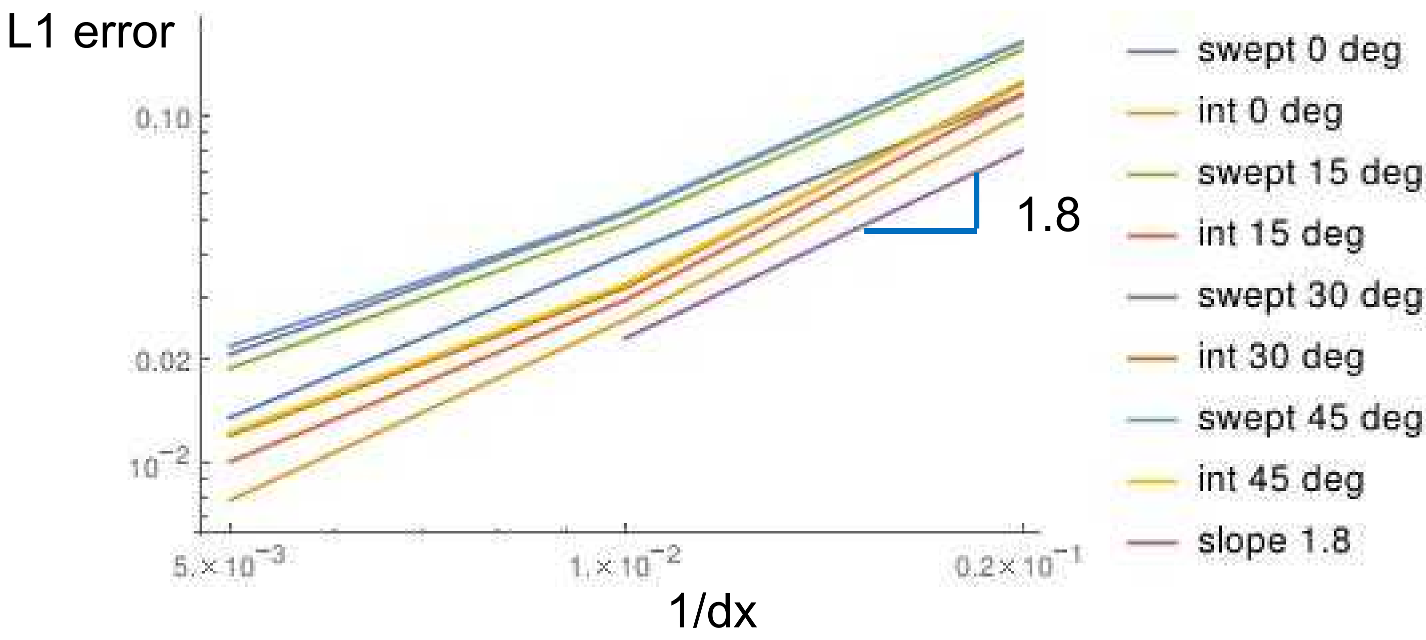
0 degrees 15 degrees 30 degrees 45 degrees

100 x 100 mesh



Translation Test Problem Spatial Error

- Problems run with 3 levels of mesh refinement (1/50, 1/100, 1/200)
- Order of error is between 1.4 and 2.0
- Intersection remap errors are below the corresponding swept remap errors



Expansion Test Problem Description

- Gaussian densitv distribution

$$\rho = 20 \exp^{-10\left[(x_c - x_{disk})^2 + (y_c - y_{disk})^2\right]/r_{disk}}$$

- Nodal velocities are specified in input (no momentum fluxing is used)

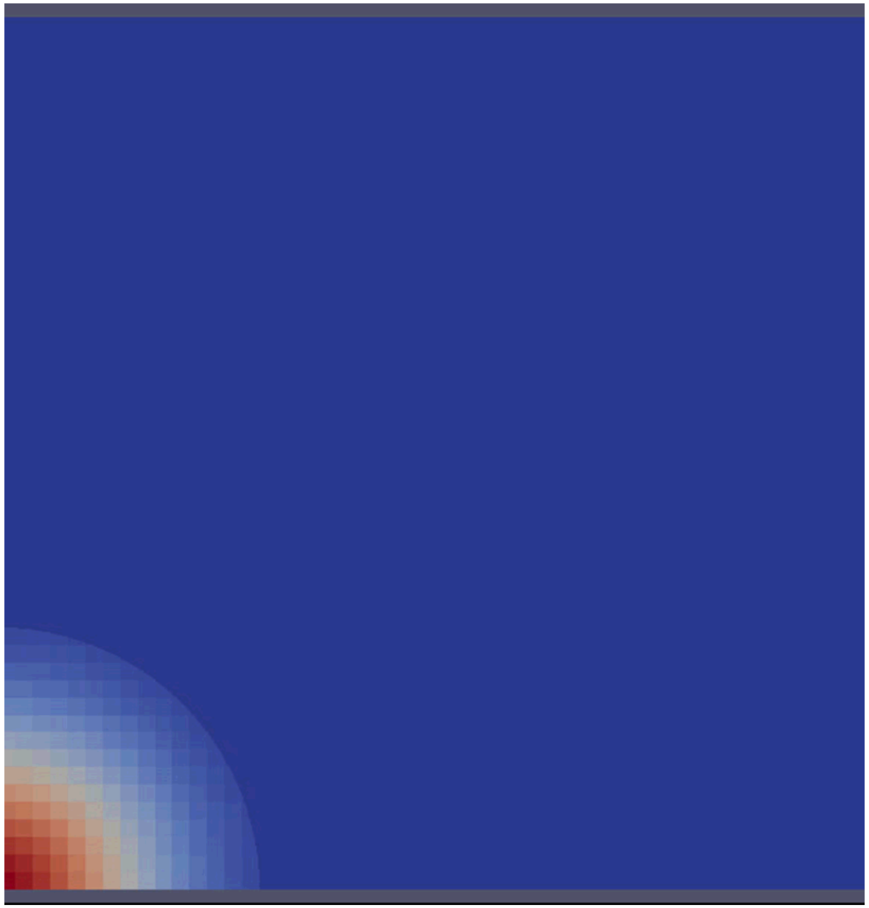
$$\theta = \arctan(N_x, N_y)$$
$$r = \sqrt{N_x^2 + N_y^2}/1.414 \quad \vec{u} = ur\cos(\theta)\hat{i} + ur\sin(\theta)\hat{j}$$

where $u = 1.0$

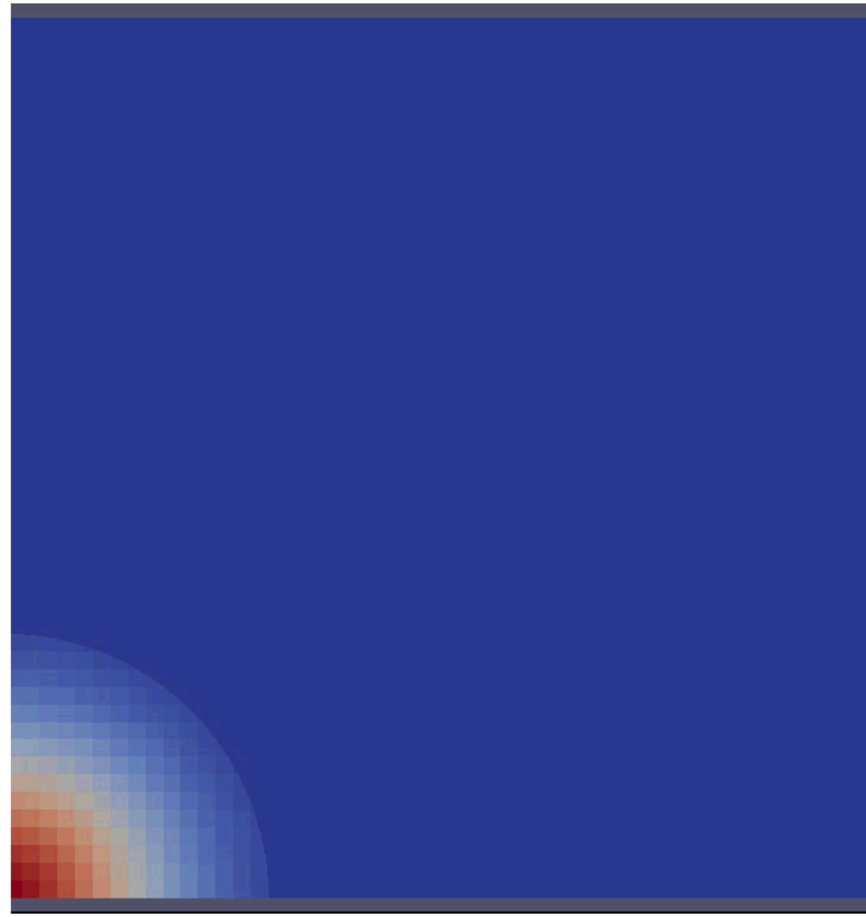
$$if \ (t > t_{mid}) u = -1.0$$

- Disk expands away from origin position and back
- Accuracy is measured by L2 error of each element
- Error compares the starting element mass in each element with the problem's ending material mass
- Second order interpolation is used for both swept and intersection remaps
- Fixed time step for all angles: maximum Courant number 0.4

Expansion Test Problem (50 x 50)

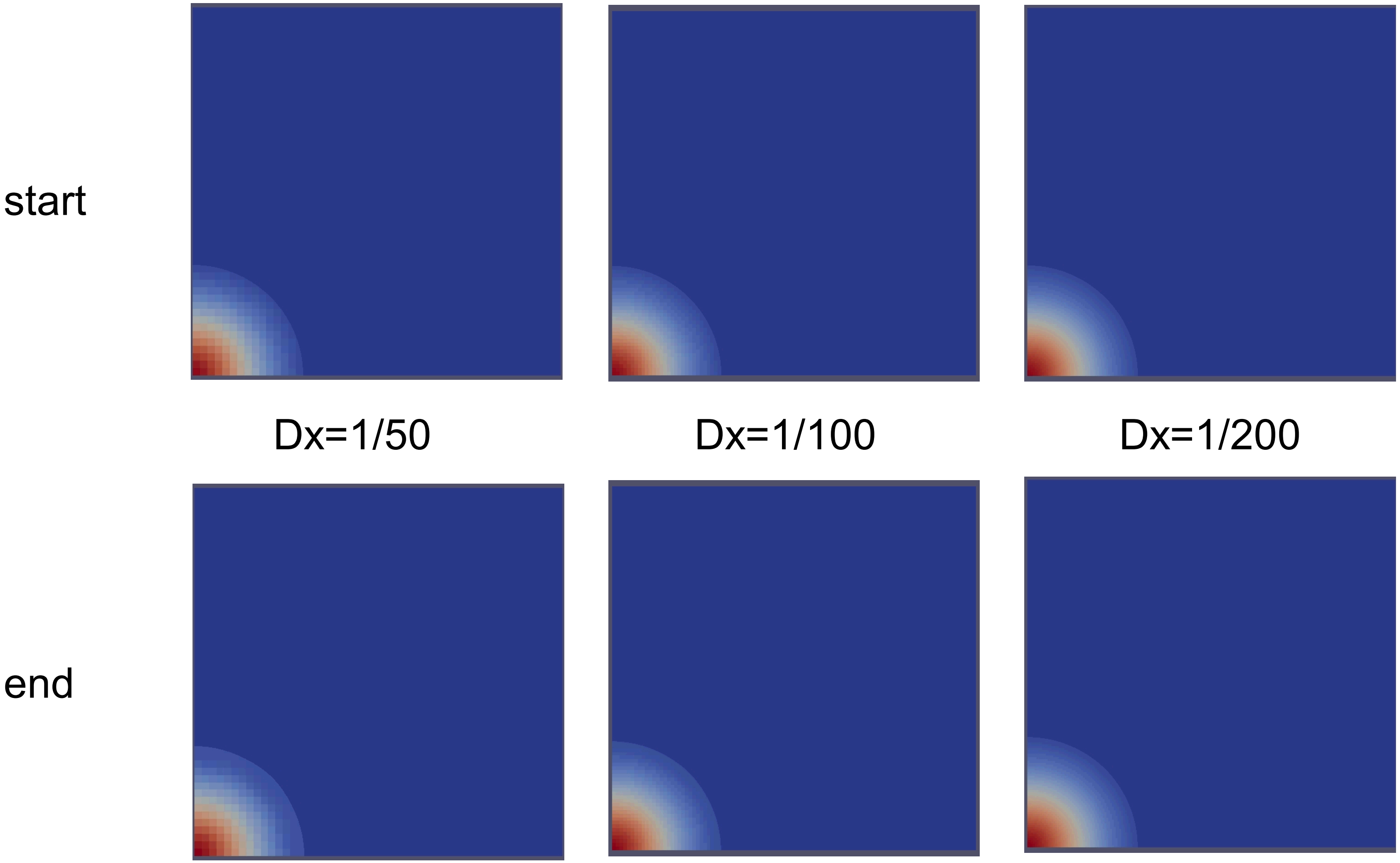


swept

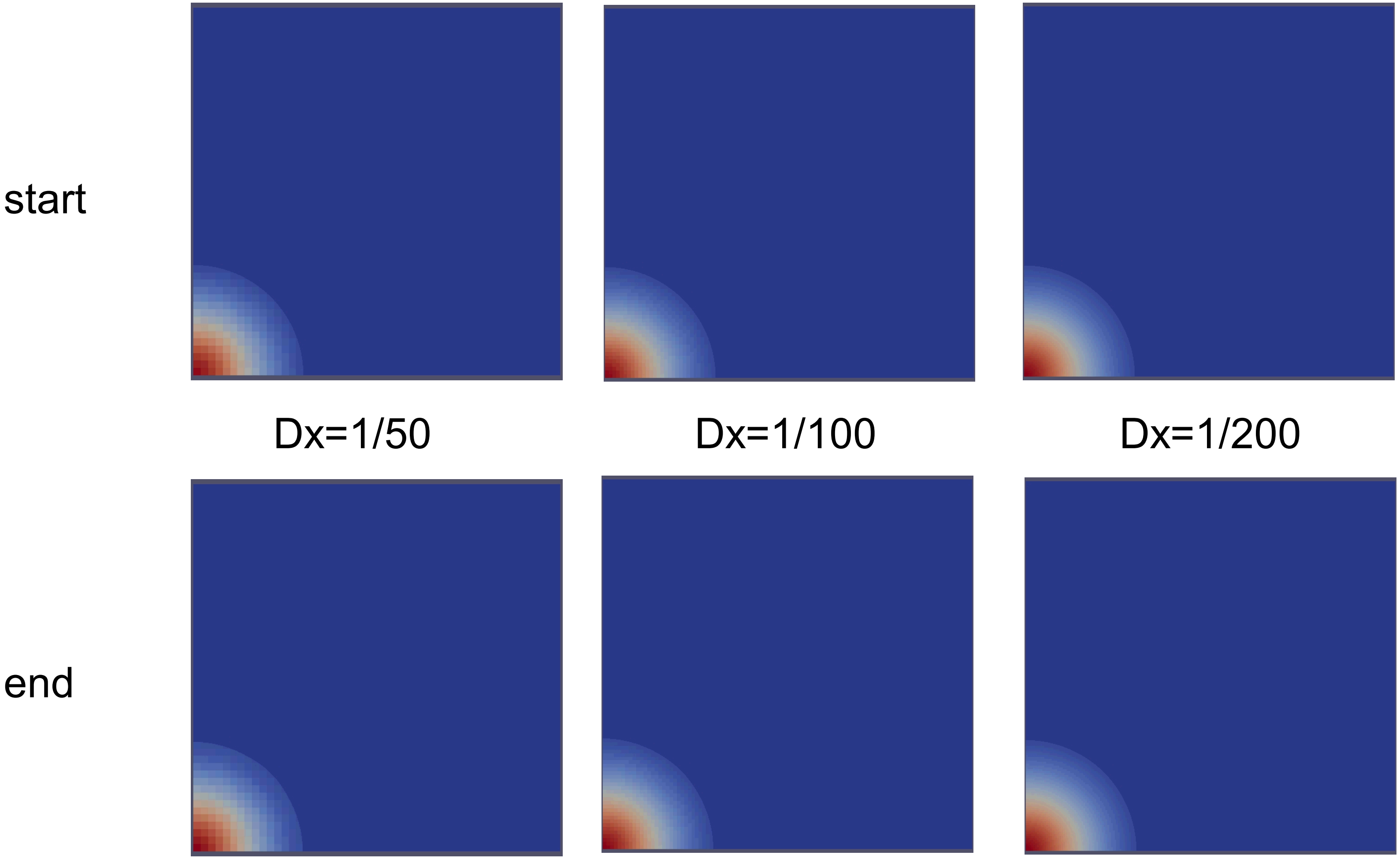


intersection

Expansion Test Problem, Swept

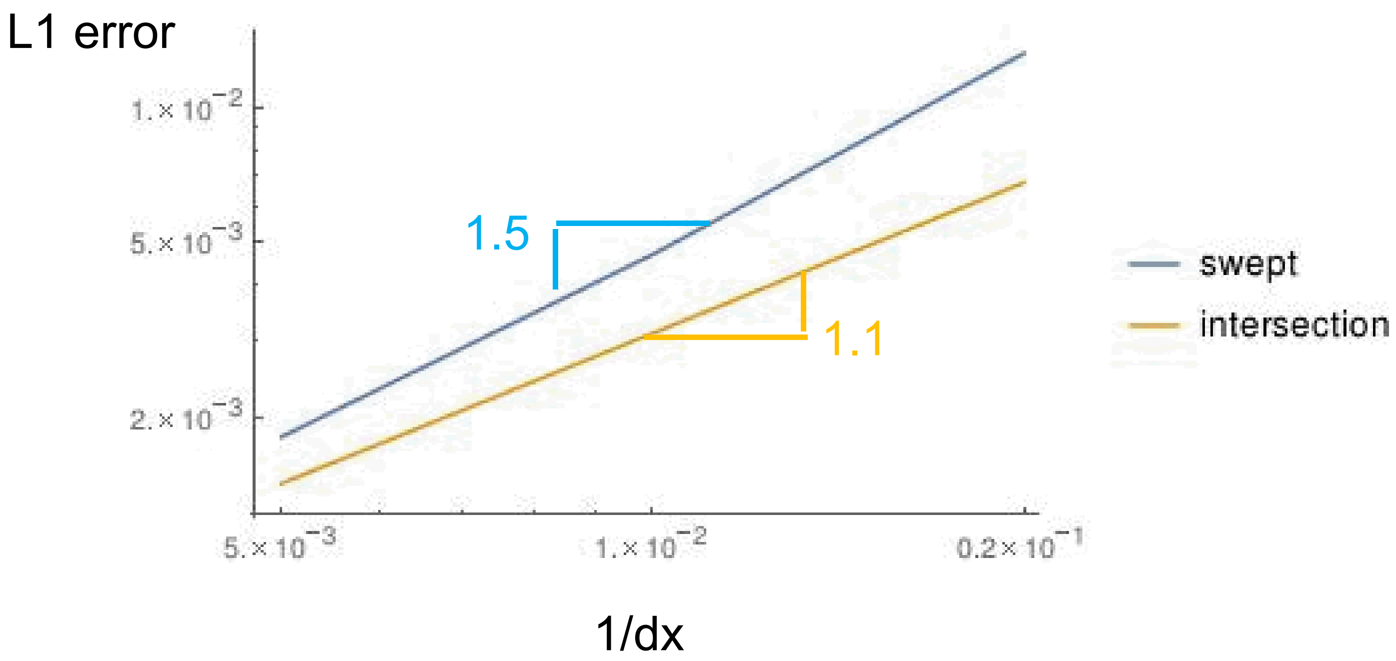


Expansion Test Problem, Intersection



Expand Test Problem Spatial Error

- Problems run with 3 levels of mesh refinement (1/50, 1/100, 1/200)



Distort Test Problem Description

- Gaussian densitv distribution

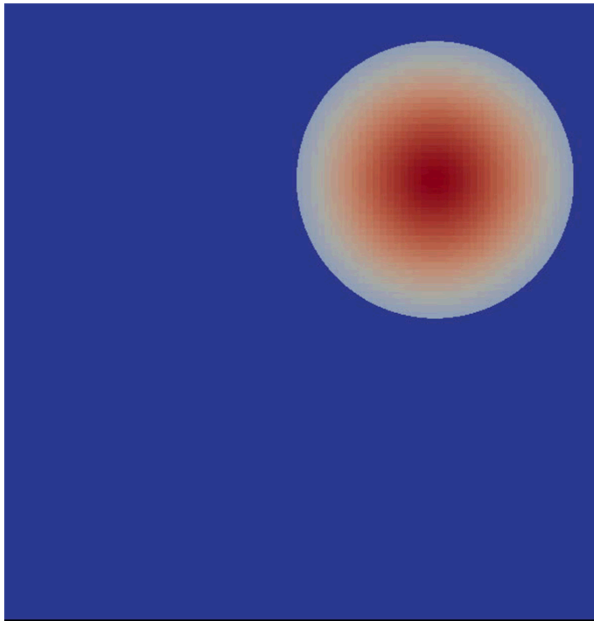
$$\rho = 20 \exp^{-10\left[(x_c - x_{disk})^2 + (y_c - y_{disk})^2\right]/r_{disk}}$$

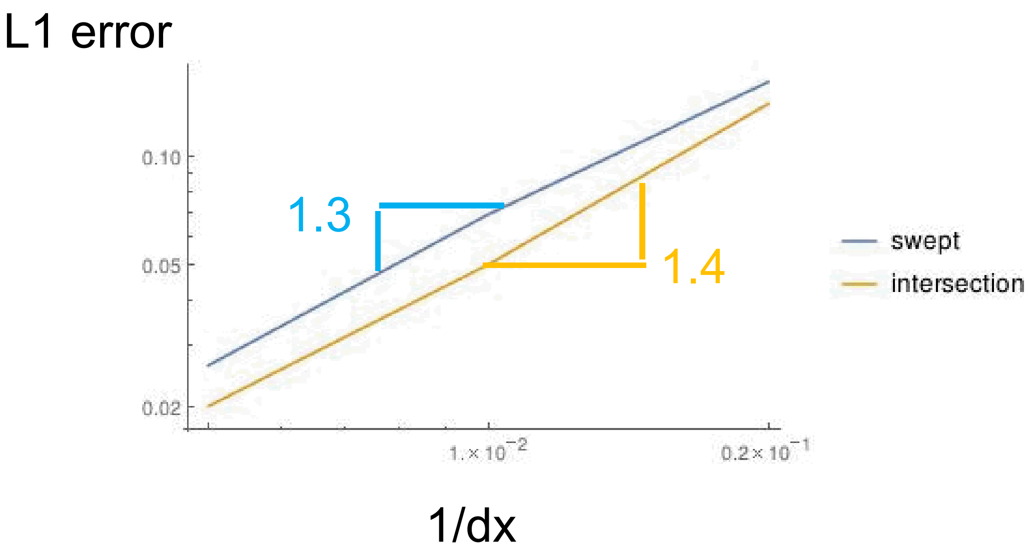
- Nodal velocities are specified in input (no momentum fluxing is used)

$$\begin{aligned}\vec{V}_x &= 2sin(2\pi N_y)\sin^2(\pi N_x)\cos(\pi t/t_{end}) \\ \vec{V}_y &= -2sin(2\pi N_x)\sin^2(\pi N_y)\cos(\pi t/t_{end})\end{aligned}$$

- Disk is translated and distorted until motion is reversed and moves back to starting position
- Accuracy is measured by L1 error of each element
- Error compares the starting element density in each element with the problem’s ending material density
- Second order interpolation is used for both swept and intersection remaps
- Fixed time step for all angles: maximum Courant number 0.4

Distort Test Problem





Intersection remap (200 by 200)

Preliminary Conclusions

- Intersection remap has lower error magnitudes than swept remap
- To conclusively demonstrate that the error reduction is due to the remap algorithm, both must use a common interpolation algorithm
- Both algorithms have approximately the same convergence rate; but the errors for intersection remap are always smaller.
- In translation tests, the significant portion of errors for both remap algorithms is due to curvature errors from under-resolved interface reconstruction