

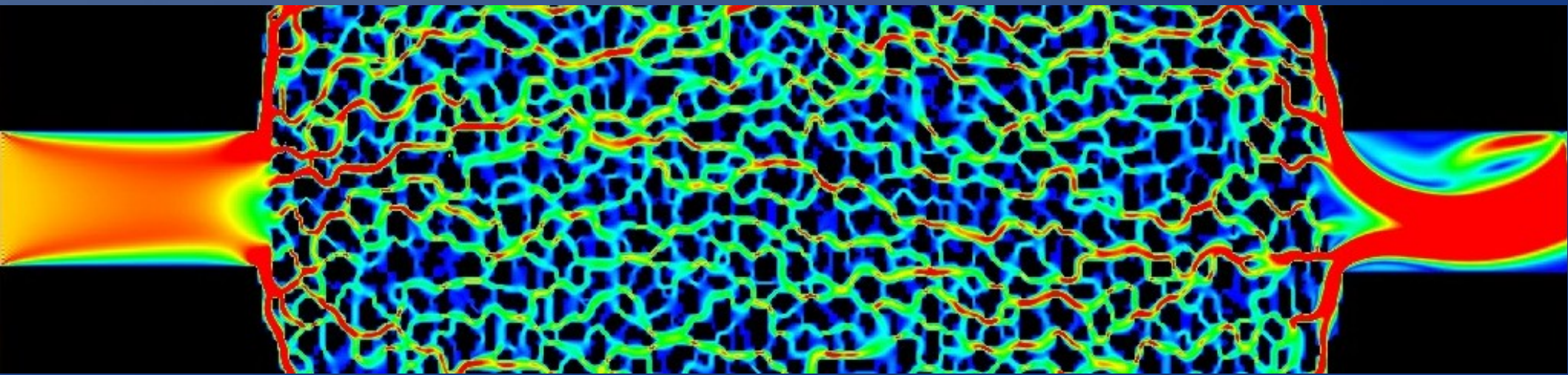
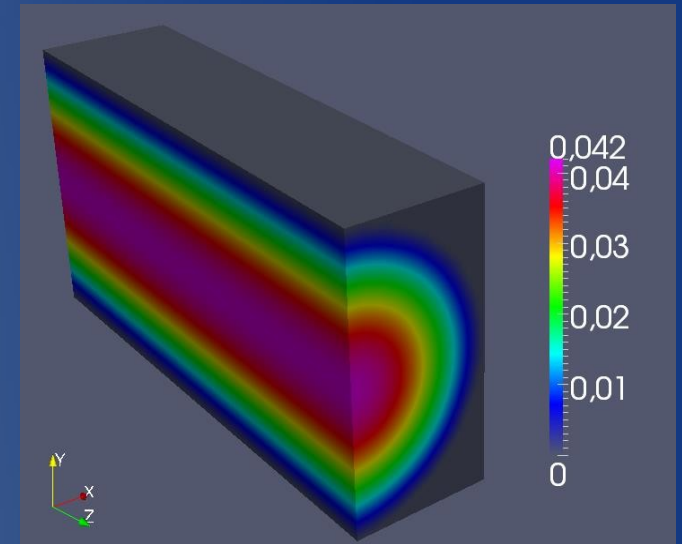
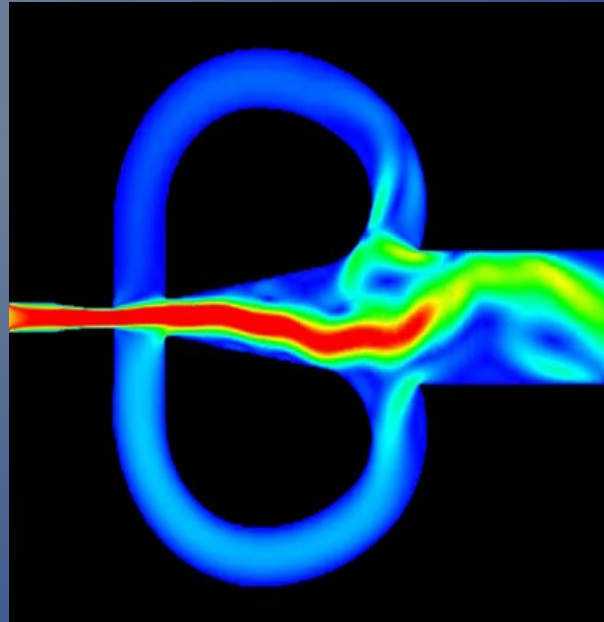
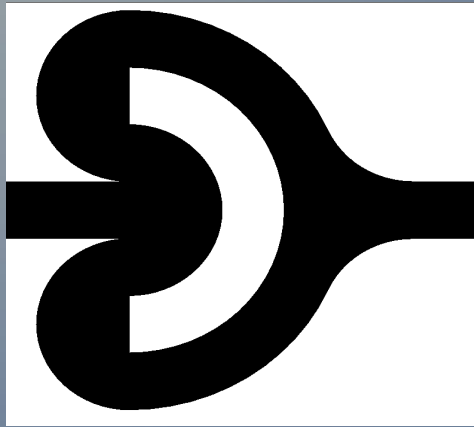
IA369E - Tópicos em Engenharia de Computação VI

Sistema interativo de visualização de dados volumétricos para simulador de microfluídica baseado no método das Redes de Boltzmann

Faculdade de Engenharia Mecânica – FEM
Departamento de Mecânica Computacional - DMC

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Motivação



Método das Redes de Boltzmann

- Método baseado em partículas com malhas
- Altamente paralelizável
- Fronteiras complexas na simulação de fluidos

Método das Redes de Boltzmann

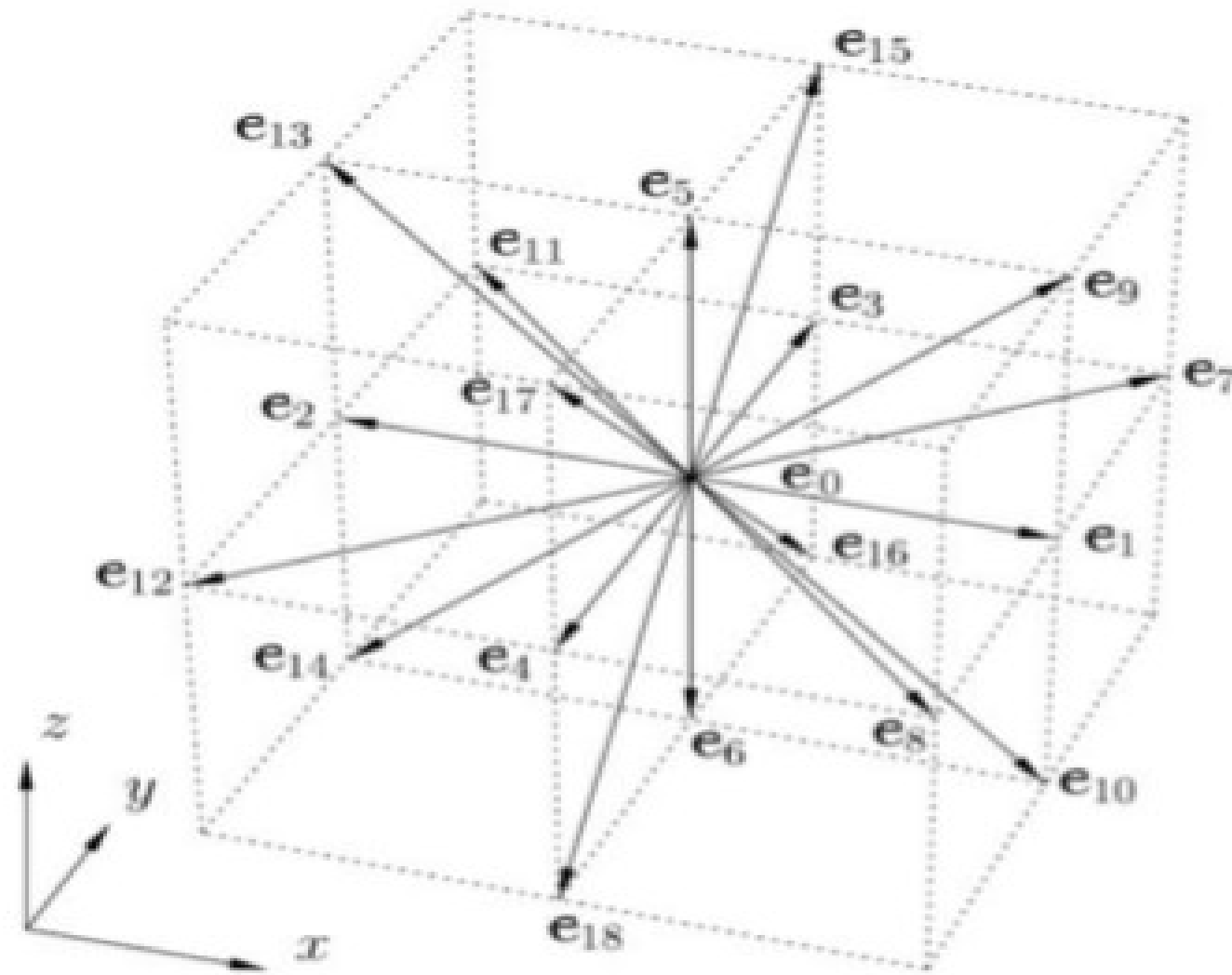


Figura 3.2. Modelo *lattice* Boltzmann D3Q19. [10]

Equação das Redes de Boltzmann

$$f_a(\mathbf{x} + \mathbf{e}_a \Delta t, t + \Delta t) = f_a(\mathbf{x}, t) - \frac{[f_a(\mathbf{x}, t) - f_a^{eq}(\mathbf{x}, t)]}{\tau}$$

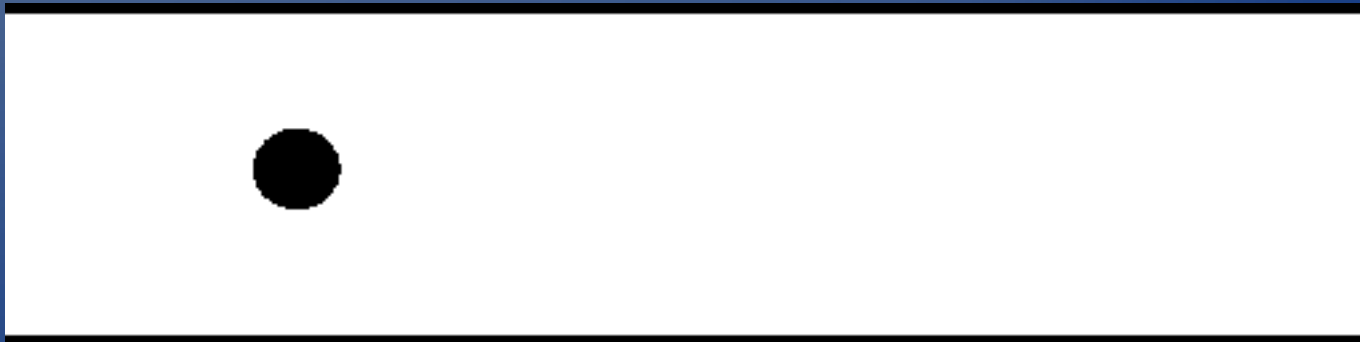
Propagação

Colisão

$$f_a^{eq}(\mathbf{x}) = w_a \rho(\mathbf{x}) \left[1 + 3 \frac{\mathbf{e}_a \cdot \mathbf{u}}{c^2} + \frac{9}{2} \frac{(\mathbf{e}_a \cdot \mathbf{u})^2}{c^4} - \frac{3 \mathbf{u}^2}{2 c^2} \right]$$

Estado anterior do simulador

- CUDA C/C++ 5.5
- Entrada:
 - Bitmap monocromático
 - Parâmetros da simulação em arquivo de texto



Estado anterior do simulador

- Saída:
 - Arquivos de dados salvos no formato *vtk* com visualização no *software* Paraview

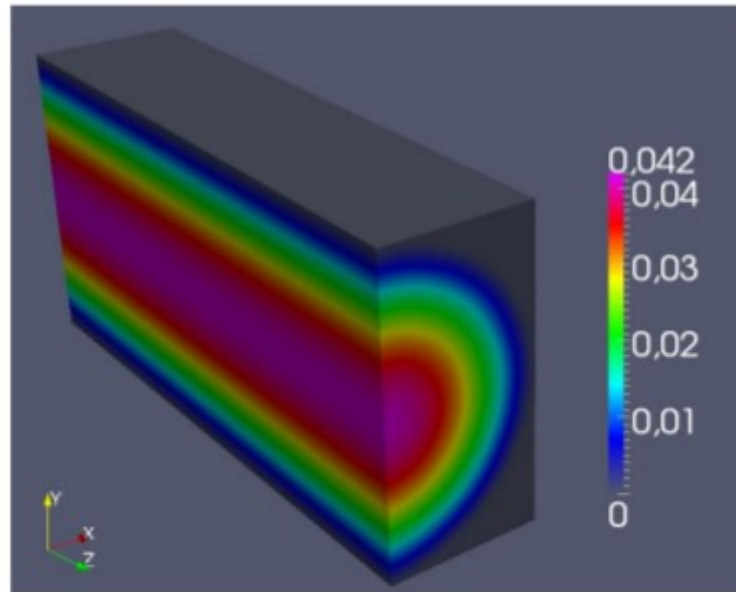
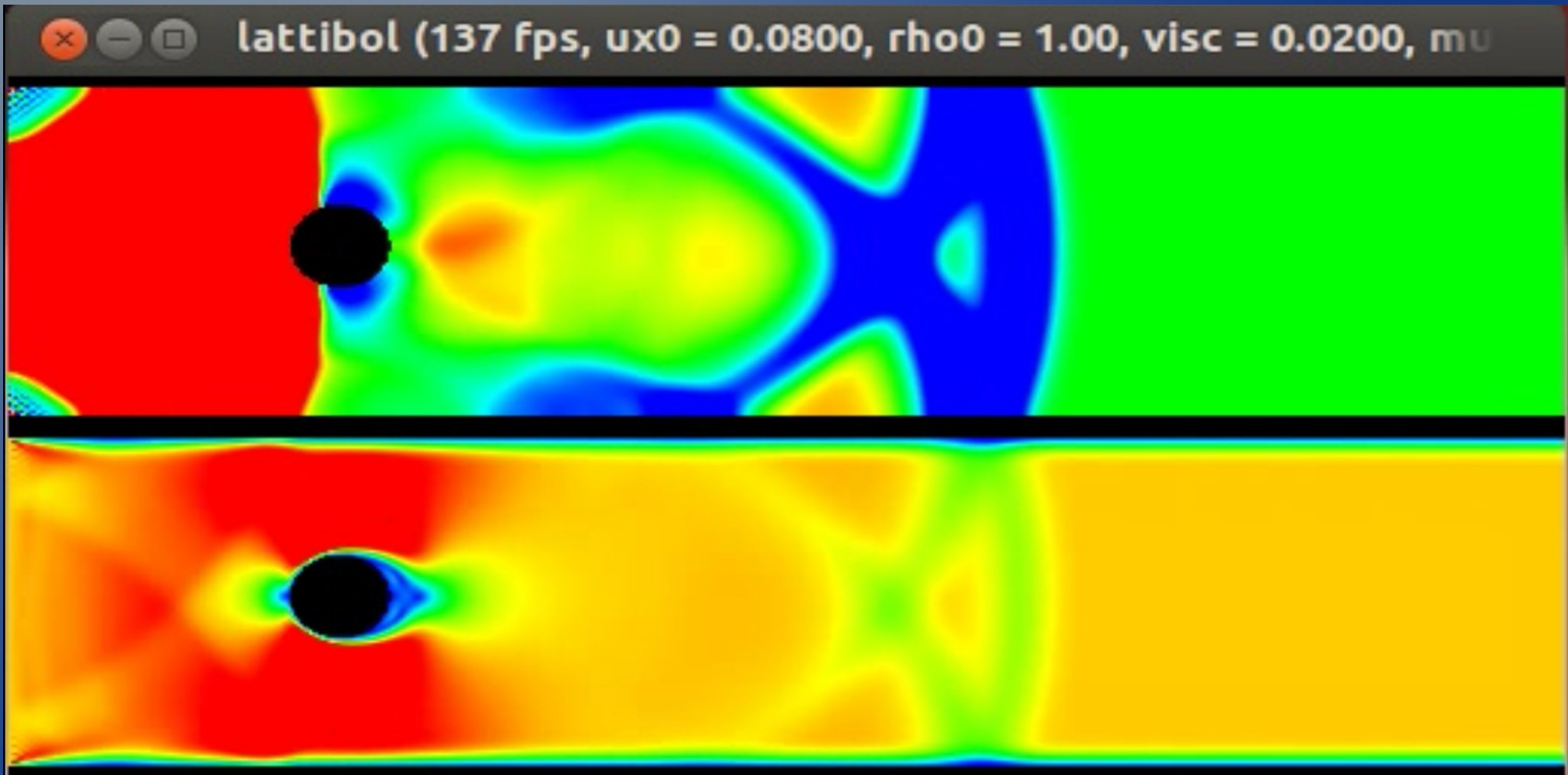


Figura 4.7. Resultado do arquivo de saída 'r0001.pvti' cortado ao meio em *x*

Estado anterior do simulador

- Visualização prévia 2D em OpenGL



The Lattice-Boltzmann Method on Optimal Sampling Lattices



(a) $Re = 300$



(b) $Re = 400$

Fig. 10. Three frames of simulations conducted on $D3bQ15$ using a higher grid resolution of $56 \times 28 \times 361$.

Equipamento

- Intel Core i7 CPU 950 @ 3.07 Ghz x 8
- 6 GB RAM
- NVIDIA GeForce GTX 560 Ti com 384 núcelos e 1 GB RAM GDDR5

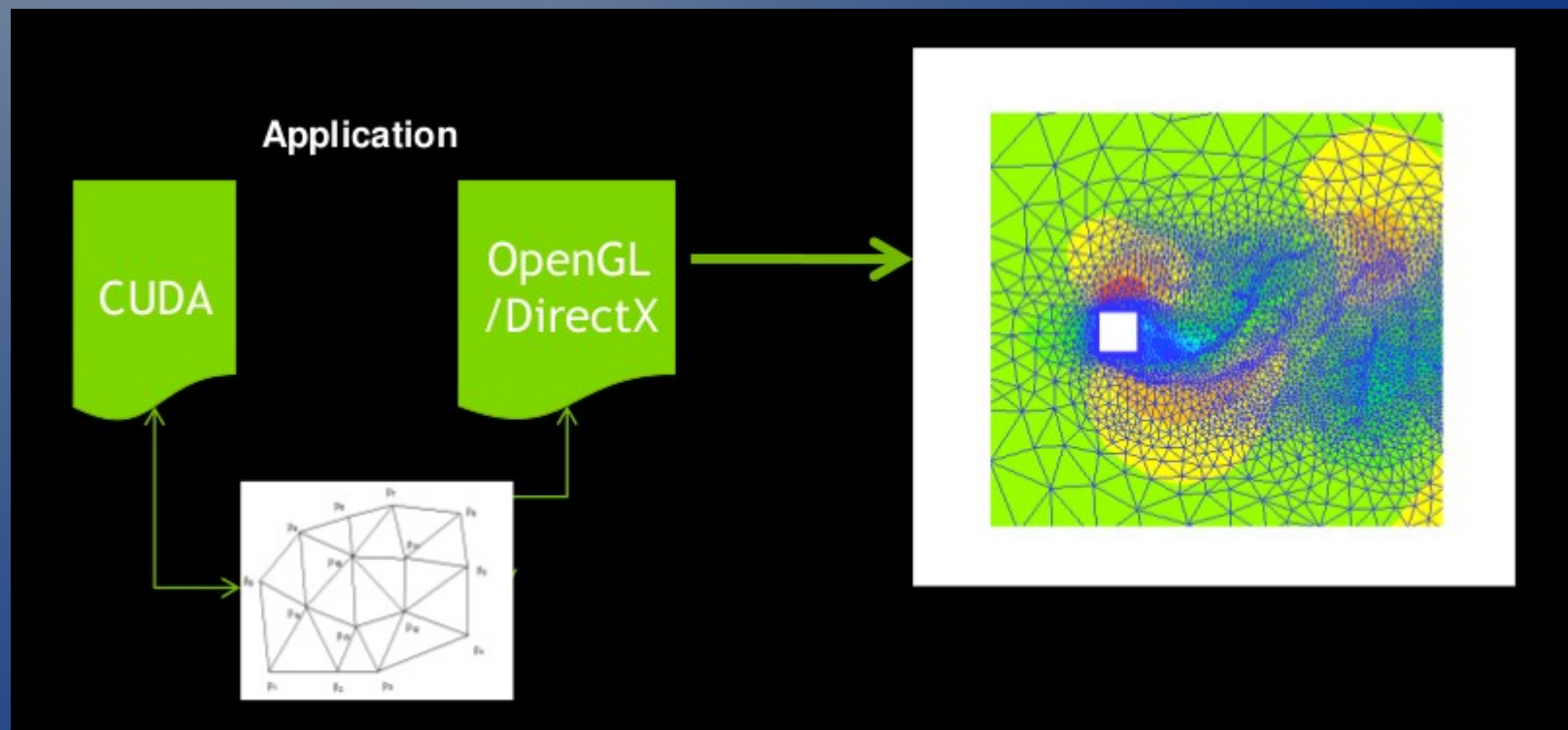


Projeto do sistema interativo para visualização de dados volumétricos

- Representação dos dados:
 - Malha 3D retangular equidistante
- Técnica de visualização:
 - Texturização 3D
- OpenGL, GLSL e Qt 5.1

Interoperabilidade gráfica e computacional (CUDA & OpenGL)

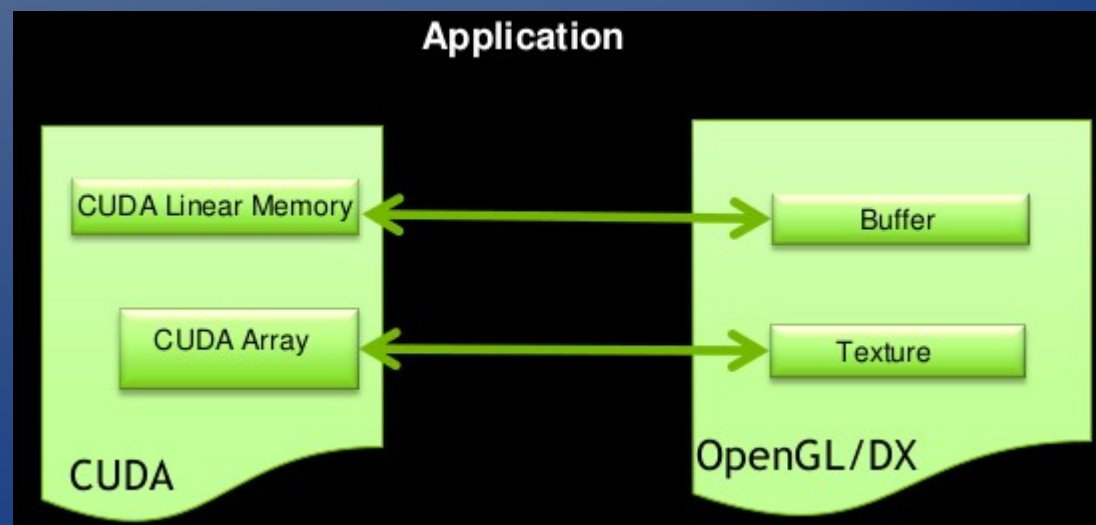
- Calcular e visualizar os mesmos dados



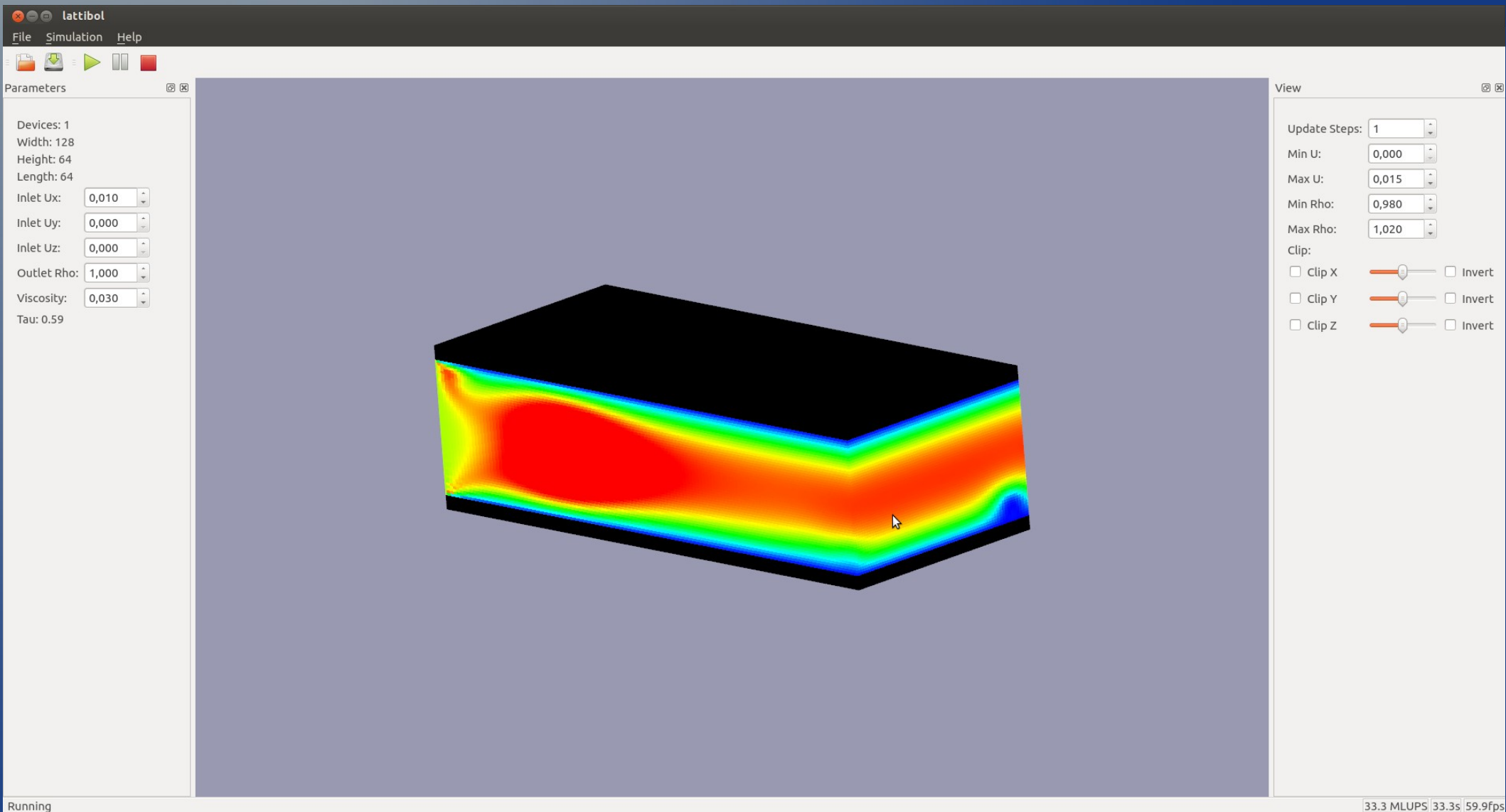
Fonte: <http://on-demand.gputechconf.com/gtc/2012/presentations/S0267A-Mixing-Graphics-and-Compute-with-Multiple-GPUs-Part-A.pdf>

Interoperabilidade gráfica e computacional (CUDA & OpenGL)

- OpenGL configura os objetos
- A cada quadro:
 - Registo/Desregisto dos objetos com contexto computacional
 - Mapeamento/Desmapeamento dos objetos para/de o contexto computacional



Sistema interativo para visualização de dados volumétricos





Parâmetros da simulação online

Quantidade de GPUs

Tamanho do domínio

Parâmetro de relaxação



Parameters  



Devices: 1



Width: 128



Height: 64



Length: 64

Inlet Ux:  

Inlet Uy:  

Inlet Uz:  

Outlet Rho:  

Viscosity:  

Tau: 0.59

Velocidade de entrada
em cada eixo

Densidade e viscosidade
do fluido

Medidas de desempenho

The screenshot displays the 'lattibol' simulation software interface. The main window shows a 3D visualization of a flow field around a rectangular object, rendered with a color gradient from blue (low velocity) to yellow (high velocity). The interface includes a 'Parameters' panel on the left, a 'View' panel on the right, and a performance overlay at the bottom.

Parameters:

- Devices: 1
- Width: 256
- Height: 128
- Depth: 128
- Inlet Ux: 0,010
- Inlet Uy: 0,000
- Inlet Uz: 0,000
- Outlet Rho: 1,000
- Viscosity: 0,030
- Tau: 0.59

View:

- Update Steps: 1
- Min U: 0,000
- Max U: 0,015
- Min Rho: 0,980
- Max Rho: 1,020
- Clip: Clip X: 128 Invert, Clip Y: 64 Invert, Clip Z: 64 Invert
- Cursor X: 128
- Cursor Y: 64
- Cursor Z: 64
- Velocity Mag: 0.00968111
- Velocity X: 0.0096811
- Velocity Y: -1.06037e-05
- Velocity Z: 8.57394e-08
- Density: 0.999327

Performance Metrics (Bottom Overlay):

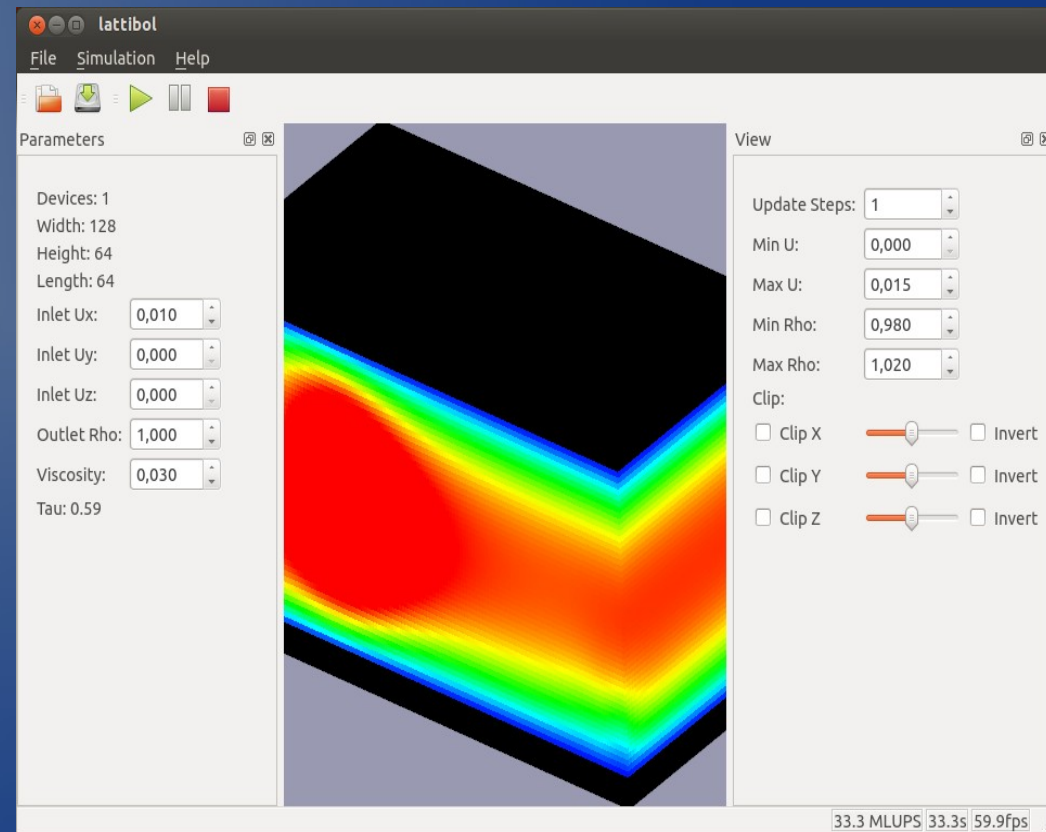
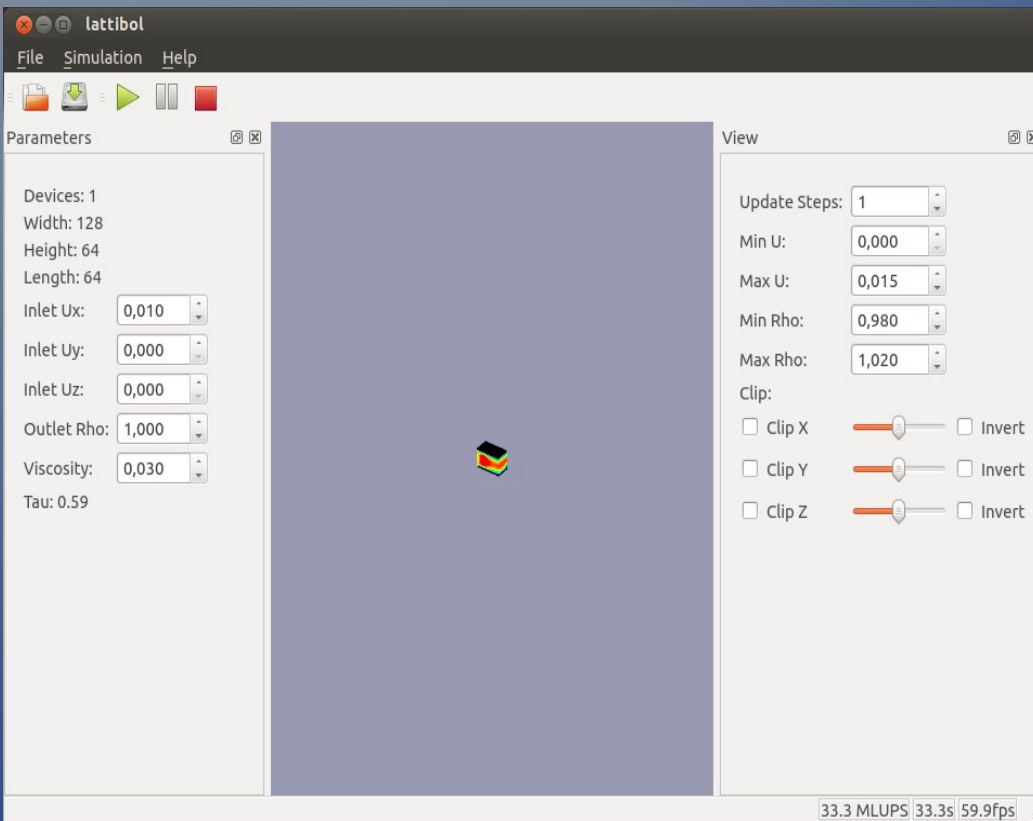
132.7 MLUPS	239.0s	29.8fps
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Performance Metrics (Bottom Status Bar):

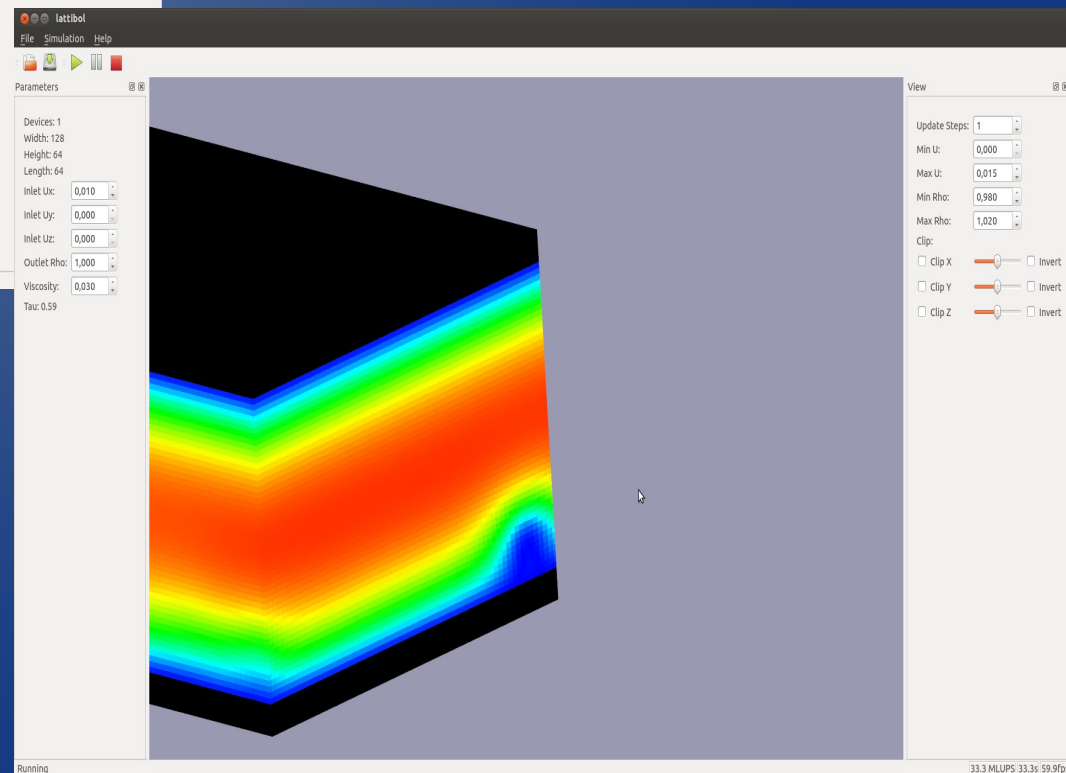
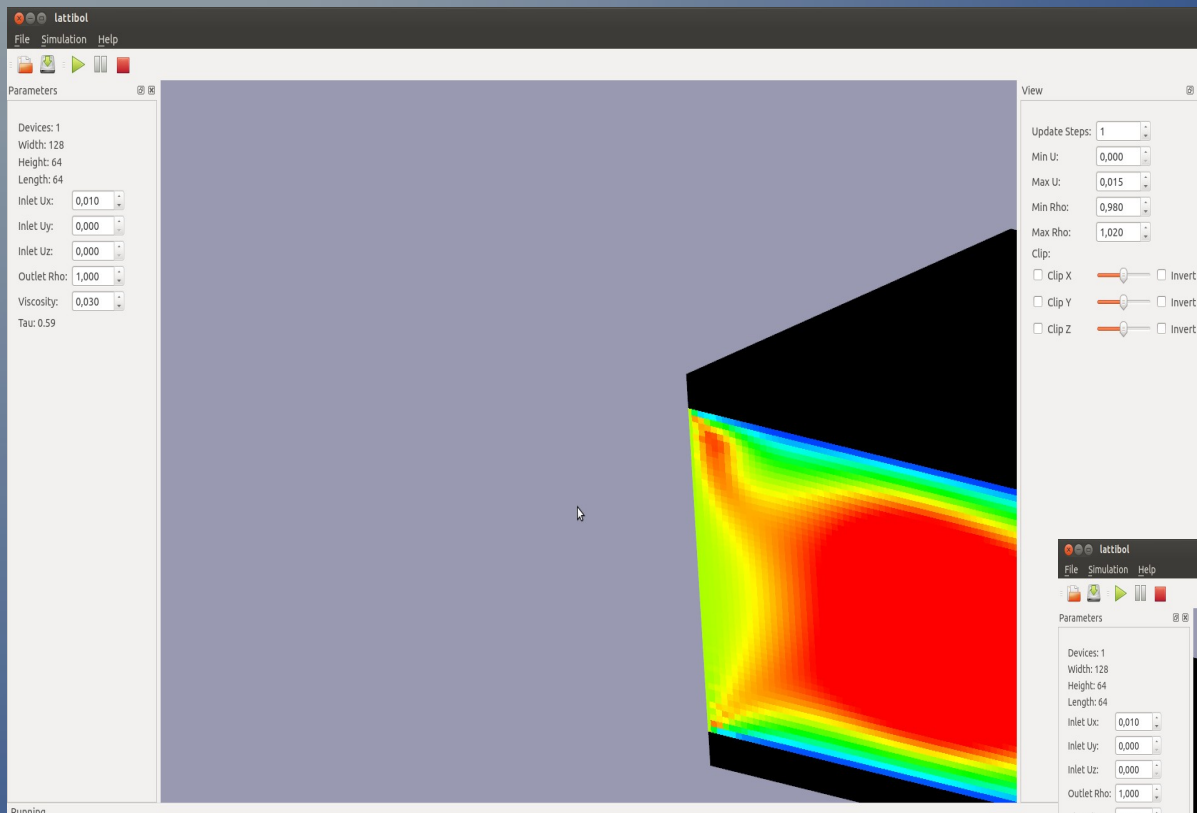
137.1 MLUPS	124.7s	30.8fps
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A red arrow points from the performance metrics in the bottom status bar to the performance metrics in the bottom overlay.

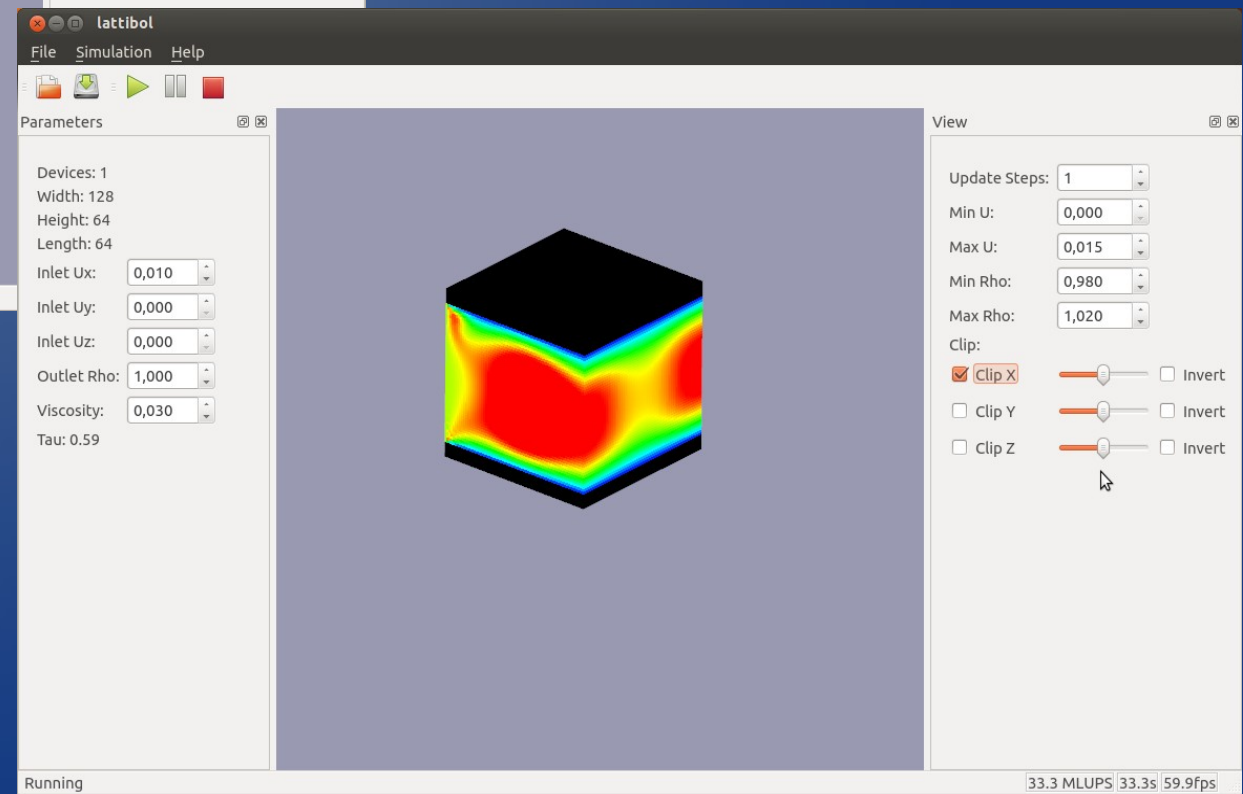
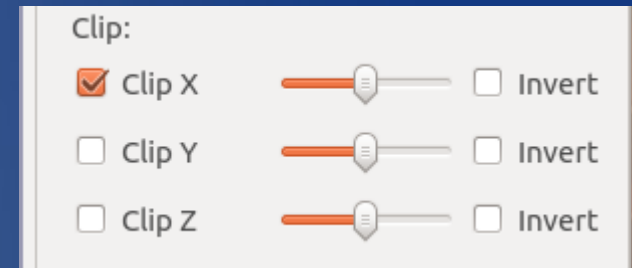
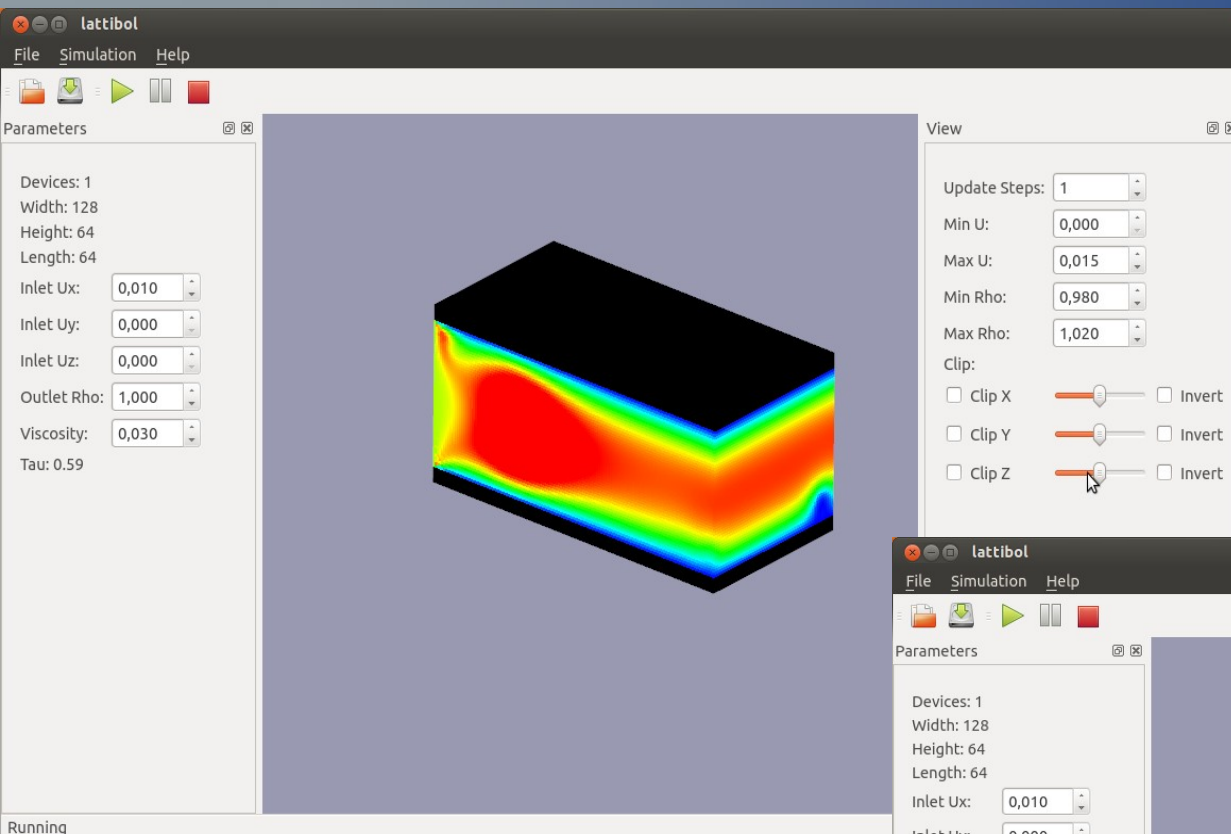
Zoom



Pan



Corte nos três eixos



Normalização de velocidades

lattibol

File Simulation Help

Parameters

Devices: 1
Width: 128
Height: 64
Length: 64
Inlet Ux: 0,010
Inlet Uy: 0,000
Inlet Uz: 0,000
Outlet Rho: 1,000
Viscosity: 0,030
Tau: 0.59

View

Update Steps: 1
Min U: 0,000
Max U: 0,015
Min Rho: 0,980
Max Rho: 1,020
Clip:
 Clip X Invert
 Clip Y Invert
 Clip Z Invert

Running

Min U: 0,000

Max U: 0,015

lattibol

File Simulation Help

Parameters

Devices: 1
Width: 128
Height: 64
Length: 64
Inlet Ux: 0,010
Inlet Uy: 0,000
Inlet Uz: 0,000
Outlet Rho: 1,000
Viscosity: 0,030
Tau: 0.59

View

Update Steps: 1
Min U: 0,015
Max U: 0,020
Min Rho: 0,980
Max Rho: 1,020
Clip:
 Clip X Invert
 Clip Y Invert
 Clip Z Invert

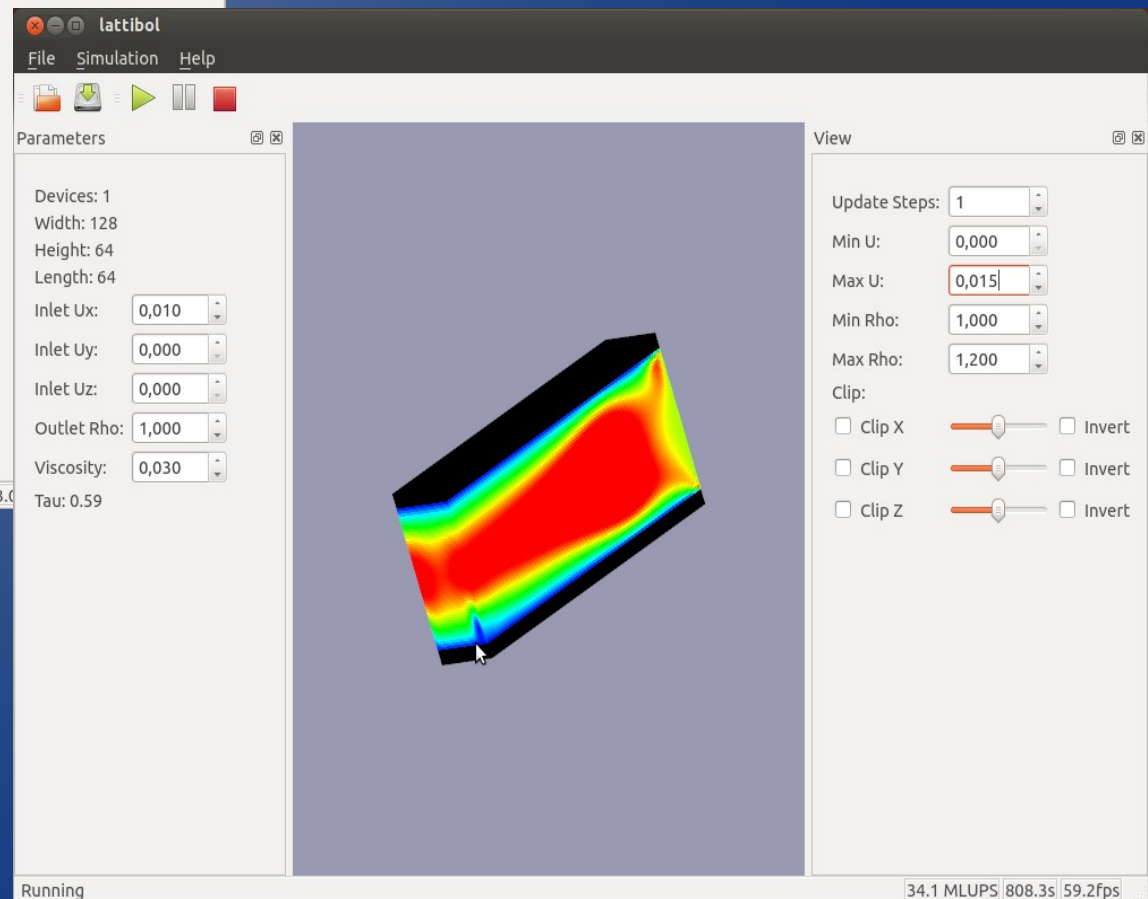
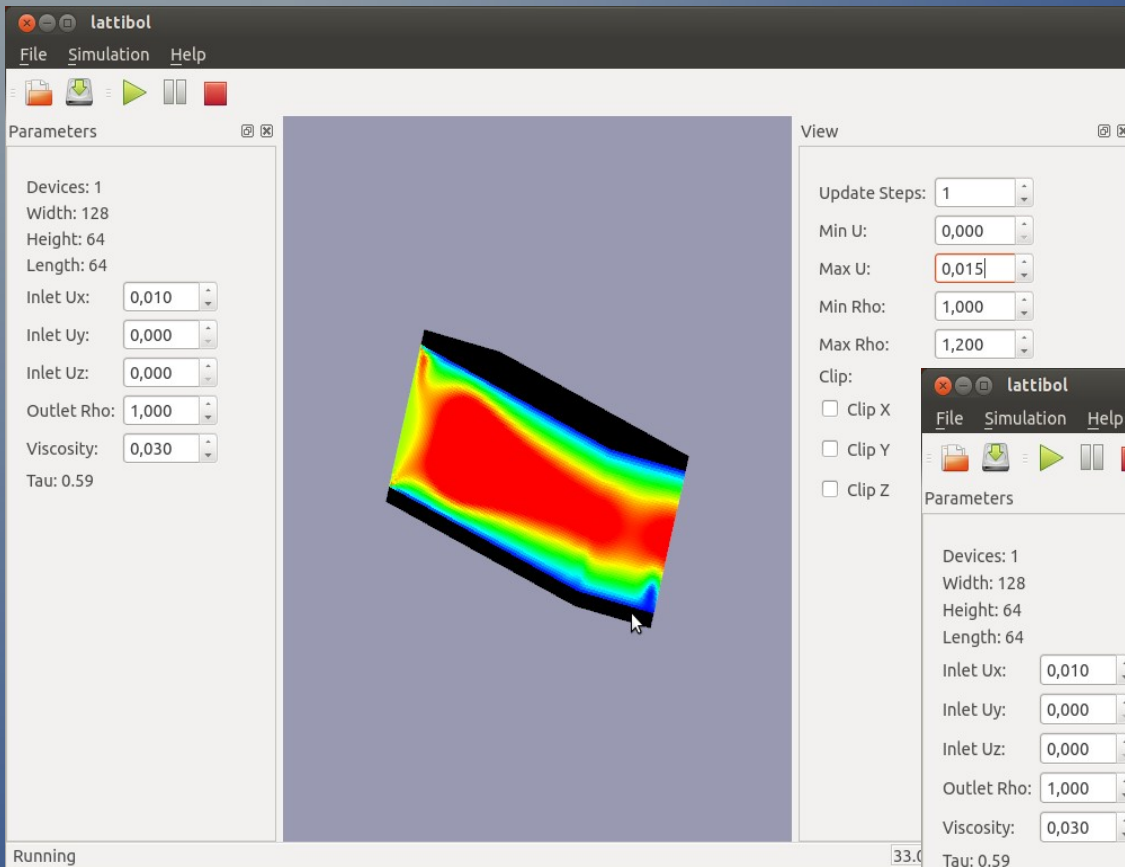
Running

33.4 MLUPS 37.6s 60.0fps

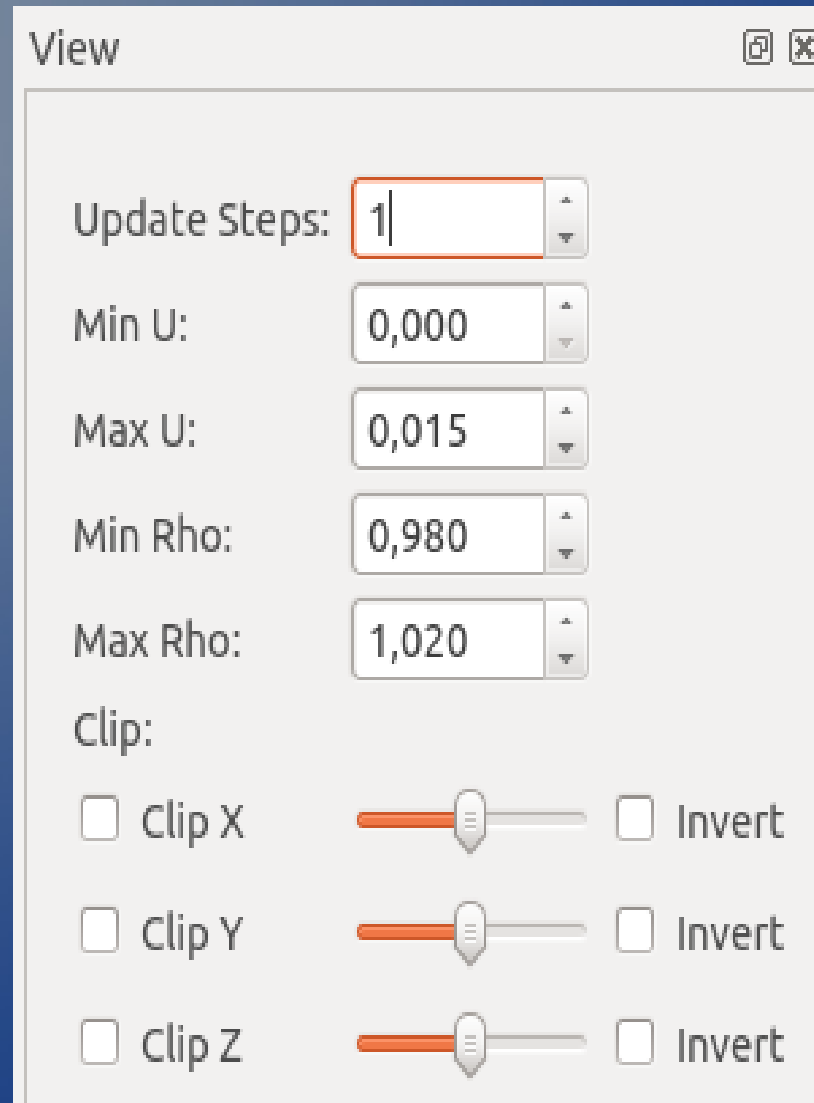
Min U: 0,015

Max U: 0,020

Rotação usando Arcball



Taxa de atualização



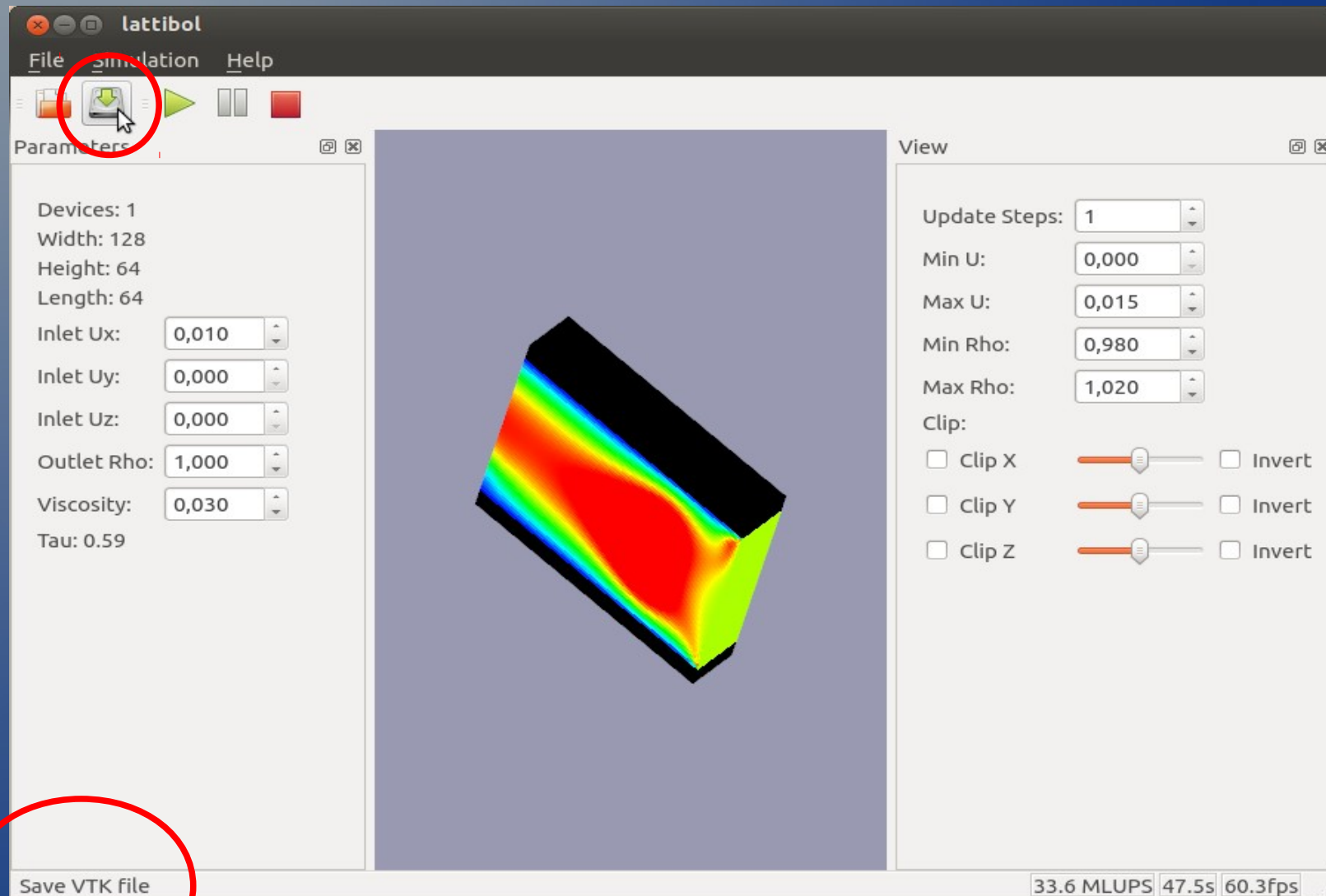
Taxa de atualização

Normalização de velocidades

Normalização de densidades

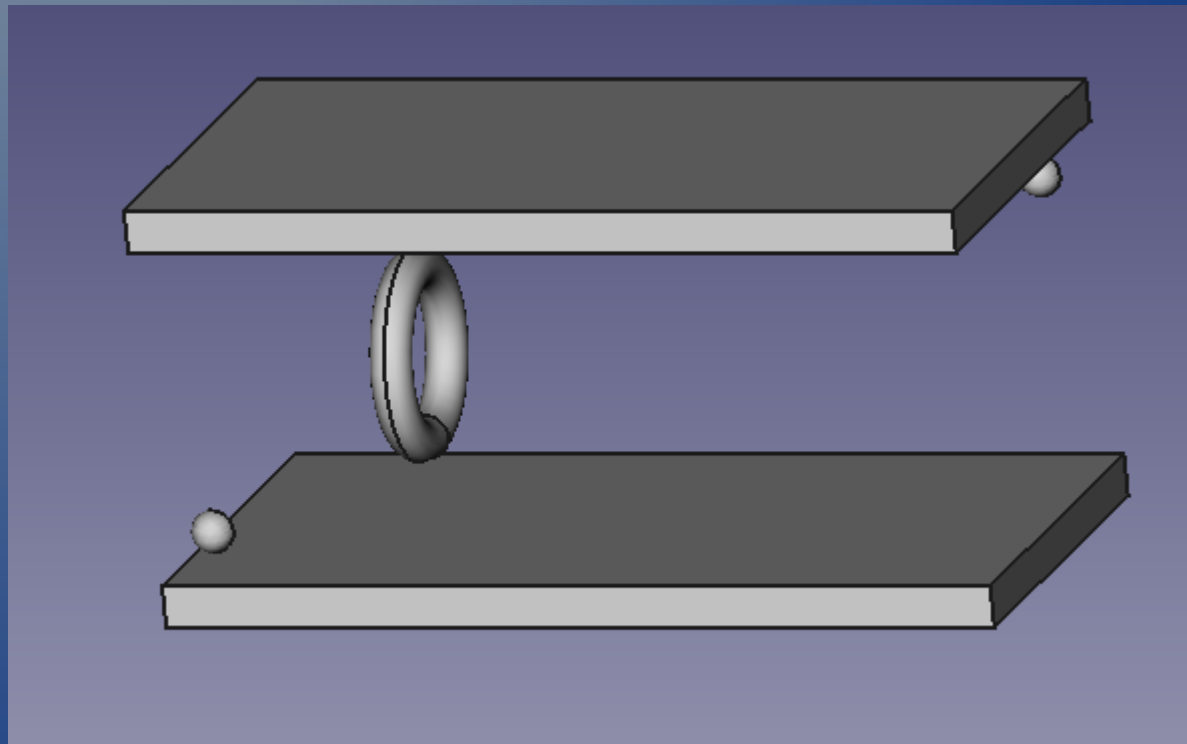
Corte nos três eixos com inversão

Salvamento de arquivos *vtk*



Entrada

- Importação de arquivo STL (Stereolithograph)



Instrumento virtual (cursor)

Parameters

Devices: 1
Width: 128
Height: 64
Length: 64
Inlet Ux: 0,010
Inlet Uy: 0,000
Inlet Uz: 0,000
Outlet Rho: 1,000
Viscosity: 0,030
Tau: 0.59

View

Update Steps: 1
Min U: 0,000
Max U: 0,015
Min Rho: 0,980
Max Rho: 1,020
Clip:
 Clip X Invert
 Clip Y Invert
 Clip Z Invert
Cursor X: 57
Cursor Y: 19
Cursor Z: 31
Value: 29695

Cursor X: 128
Cursor Y: 64
Cursor Z: 64

Velocity Mag: 0.0104403
Velocity X: 0.0104403
Velocity Y: -8.11731e-06
Velocity Z: 8.36644e-08
Density: 1.00185

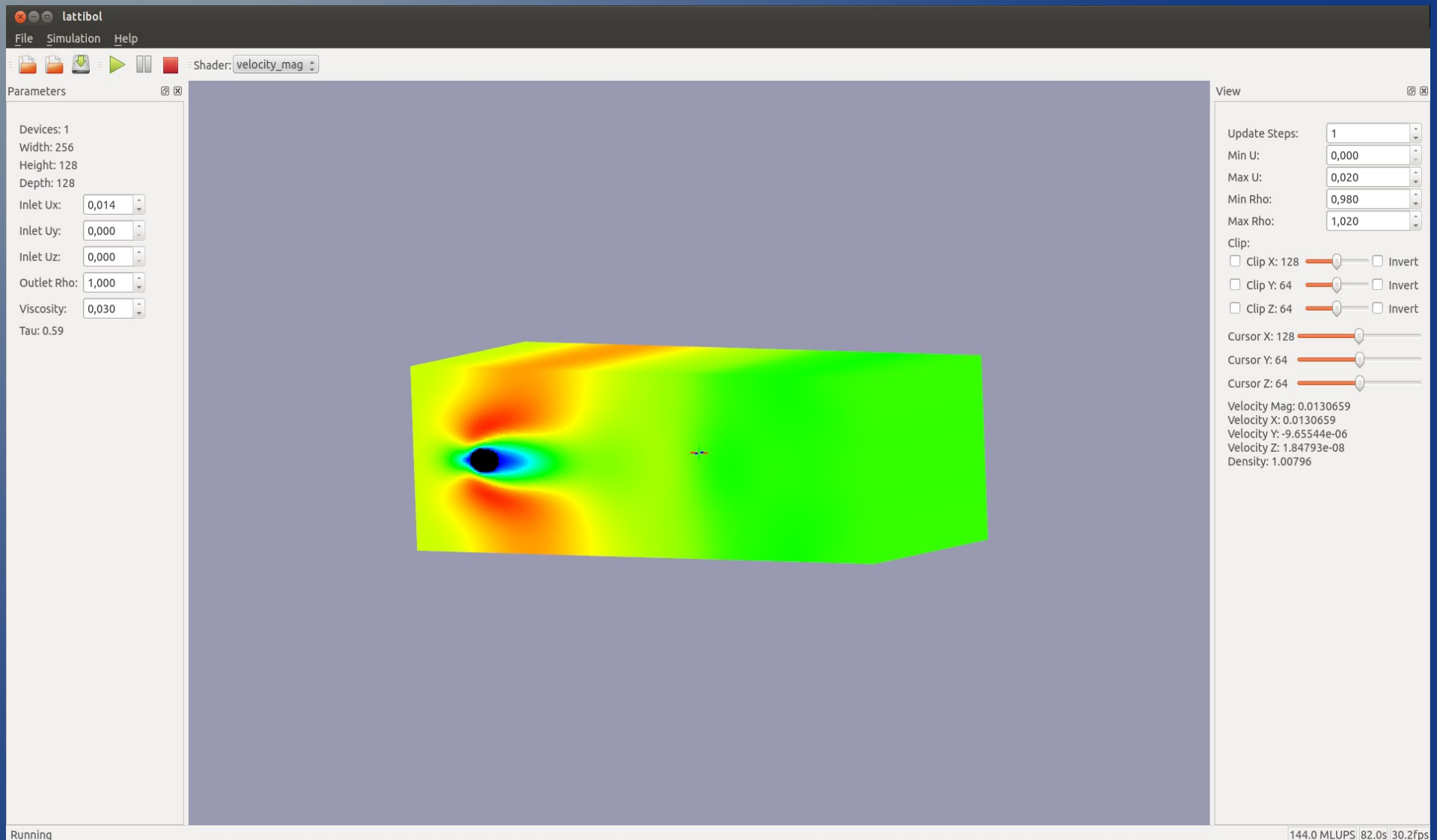
Running

Shaders - densidade

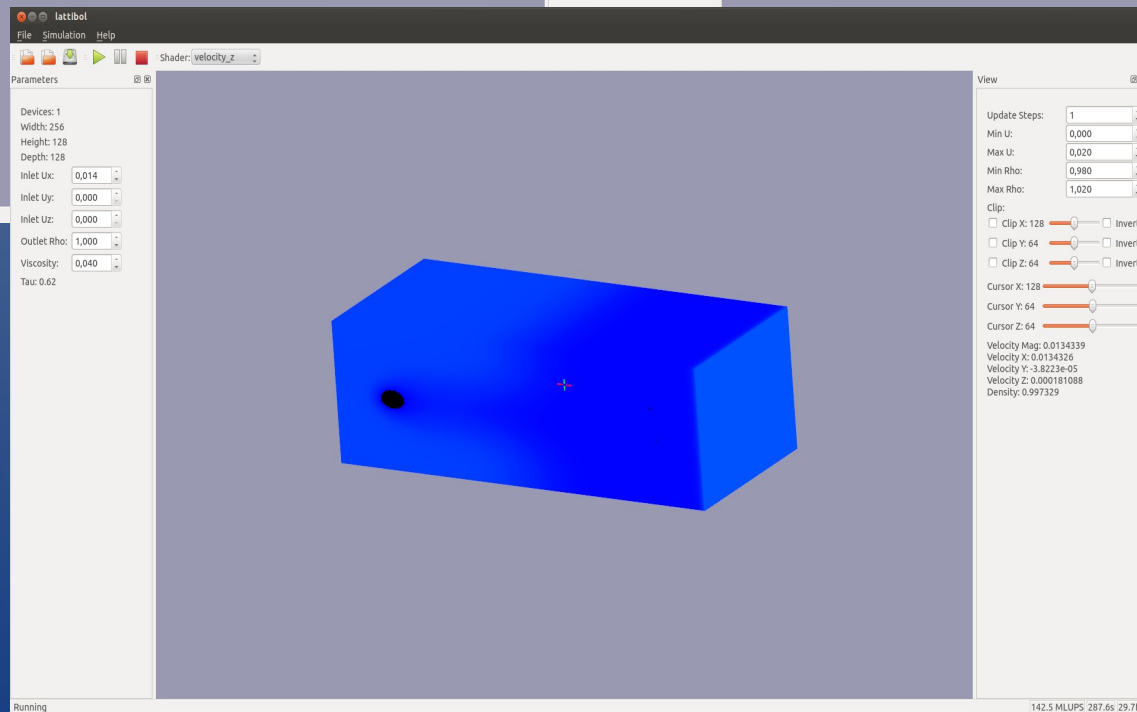
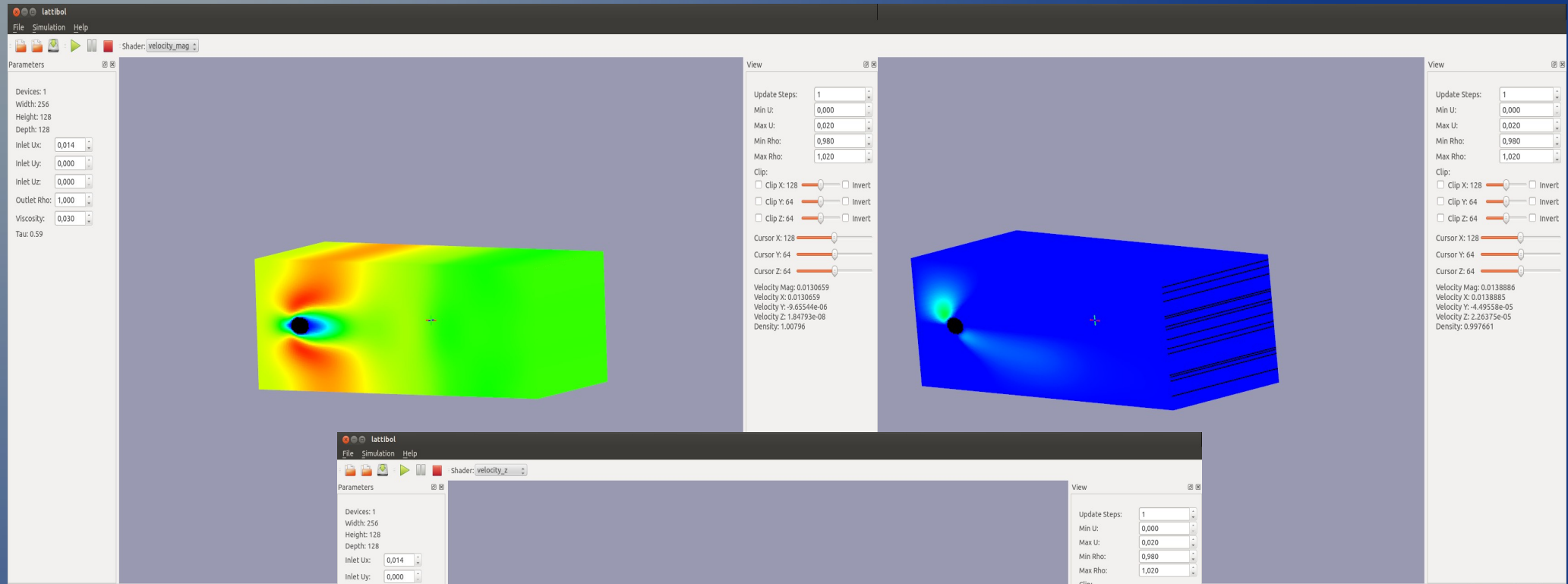
The screenshot displays the **lattibol** simulation software interface. The main window shows a 3D visualization of a rectangular domain with a central hole, rendered with a density gradient from cyan to red. The interface includes the following components:

- Menu Bar:** File, Simulation, Help
- Toolbar:** Includes icons for file operations, simulation control, and a dropdown menu for the **Shader: density**.
- Parameters Panel (Left):**
 - Devices: 1
 - Width: 256
 - Height: 128
 - Depth: 128
 - Inlet Ux: 0,014
 - Inlet Uy: 0,000
 - Inlet Uz: 0,000
 - Outlet Rho: 1,000
 - Viscosity: 0,030
 - Tau: 0.59
- View Panel (Right):**
 - Update Steps: 1
 - Min U: 0,000
 - Max U: 0,020
 - Min Rho: 0,980
 - Max Rho: 1,020
 - Clip: Clip X: 128 Invert, Clip Y: 64 Invert, Clip Z: 64 Invert
 - Cursor X: 128, Cursor Y: 64, Cursor Z: 64
 - Velocity Mag: 0.0144936
 - Velocity X: 0.0144936
 - Velocity Y: -3.82632e-06
 - Velocity Z: 8.62376e-08
 - Density: 0.993554
- Status Bar (Bottom):** Running, 143.9 MLUPS, 51.7s, 29.9fps

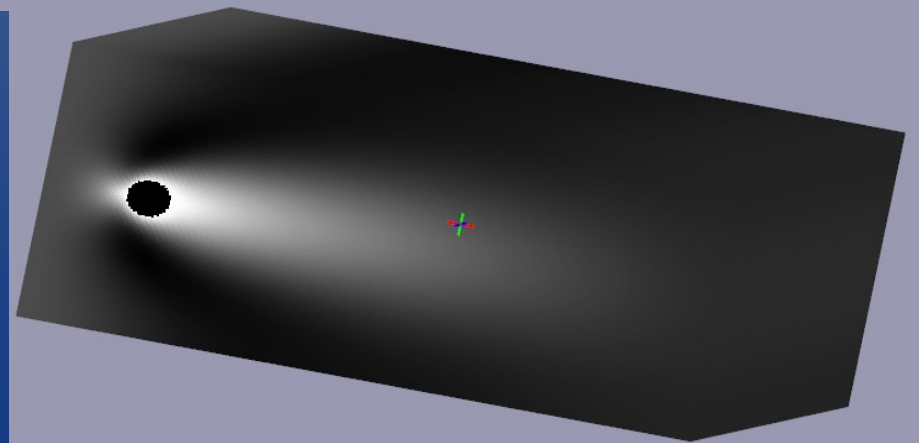
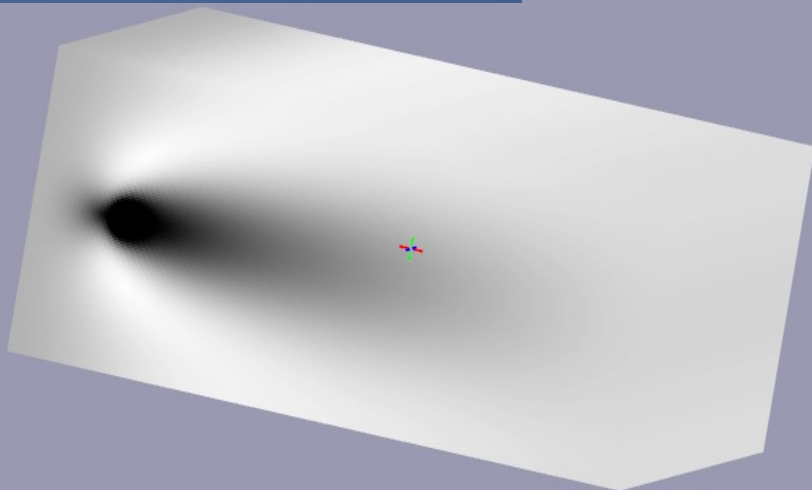
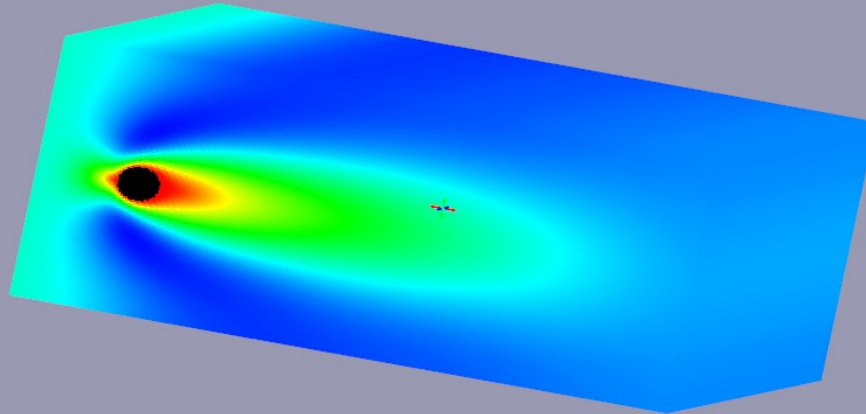
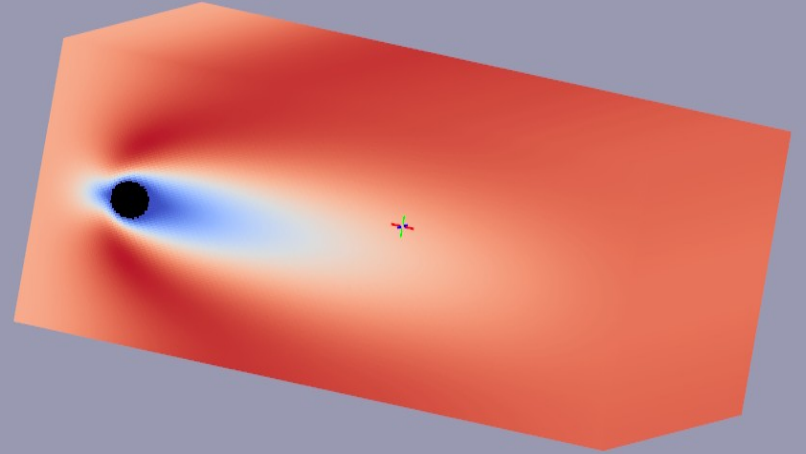
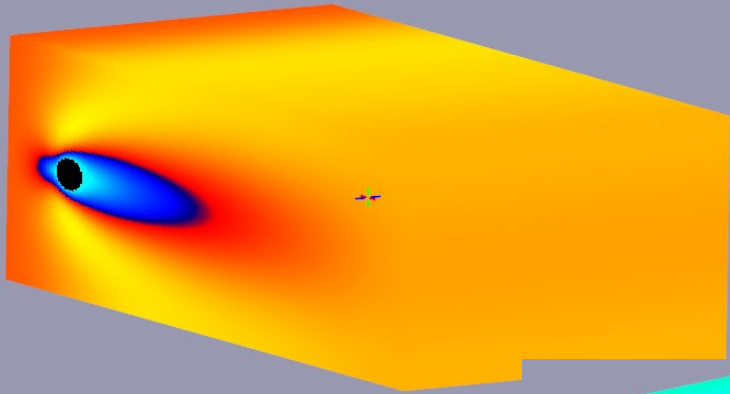
Shaders – magnitude da velocidade



Shaders – velocidade em cada eixo



Shaders – mapas de cores



Shaders – mapas de cores

The screenshot shows the 'lattibol' application window. The 'File' menu is circled in red. The 'Parameters' panel on the left lists simulation settings. The 'colormaps' folder is selected in the file browser, and its contents are listed in a table below. A red circle highlights the file list, and a red arrow points from it to a legend at the bottom of the image.

Nome	Tamanho	Modificado
blue_to_red.png	349 bytes	terça
cold_and_hot.png	398 bytes	terça
cool_to_warm.png	513 bytes	terça
grayscale.png	318 bytes	terça
red_to_blue.png	348 bytes	terça
x_ray.png	326 bytes	terça

Legend:

- blue_to_red.png: A horizontal color gradient from blue to red.
- cold_and_hot.png: A horizontal color gradient from blue to yellow.
- cool_to_warm.png: A horizontal color gradient from blue to red.
- grayscale.png: A horizontal grayscale gradient from black to white.
- red_to_blue.png: A horizontal color gradient from red to blue.
- x_ray.png: A horizontal grayscale gradient from white to black.

Conclusões e perspectivas

- A disciplina IA369 trouxe grandes avanços ao simulador:
 - Interface gráfica ao usuário
 - Visualização em tempo real
 - Ferramentas interativas
- Há maior possibilidade de trazer novos usuários:
 - Maior impacto do simulador
 - Sugestões para melhorias

Conclusões e perspectivas

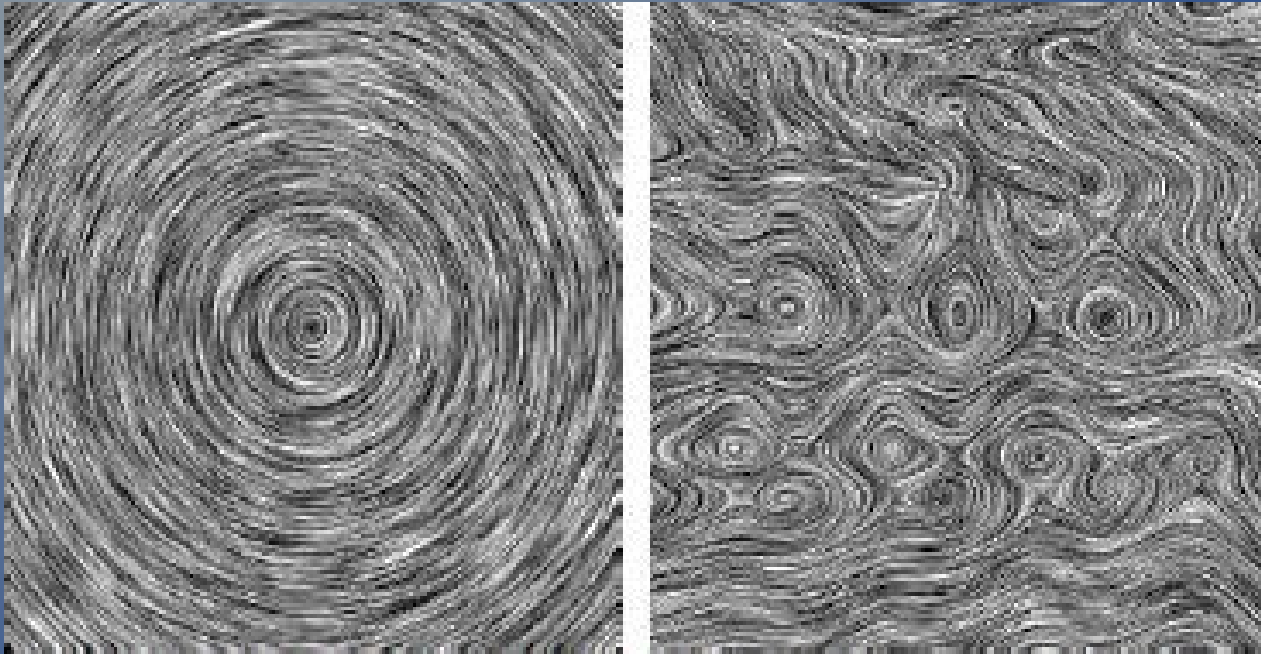


Figure 4: Circular and turbulent fluid dynamics vector fields imaged using LIC over white noise.

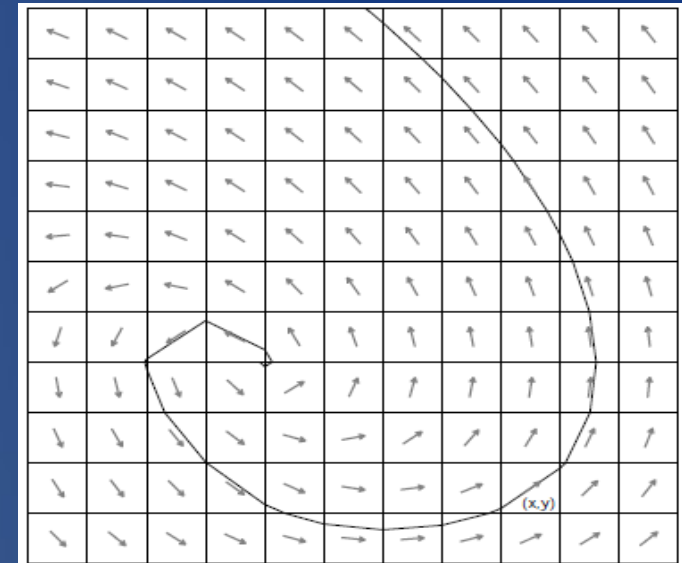
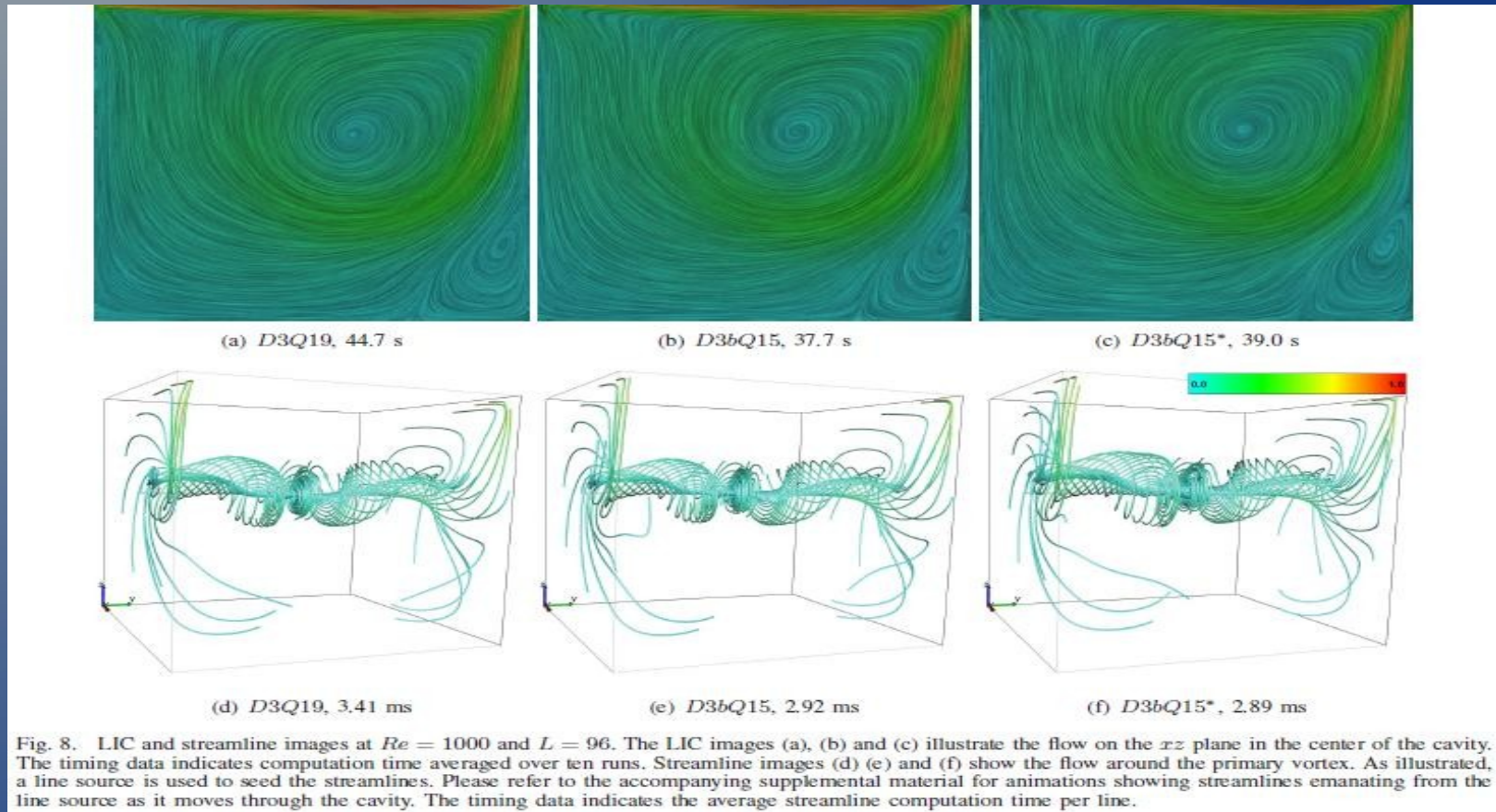


Figure 3: A two-dimensional vector field showing the local stream line starting in cell (x, y) . The vector field is the upper left corner of the fluid dynamics field in figures 2 and 4.

Cabral, B., Leedom, L.
Imaging Vector Fields Using Line Integral Convolution.

Conclusões e perspectivas



Alim, U., Entezari A. e Möller T.
The Lattice-Boltzmann Method on Optimal Sampling Lattices.
IEEE Transactions On Visualization And Computer Graphics,
Dezembro 2008