Graphics Processing Units for the Real-time Linear Elastostatic Simulation of Liver

International Conference on Advanced Computing & Communication Technologies
(*ACCT11*)
20-22 January 2011
RG Education Society
Rohtak, Haryana

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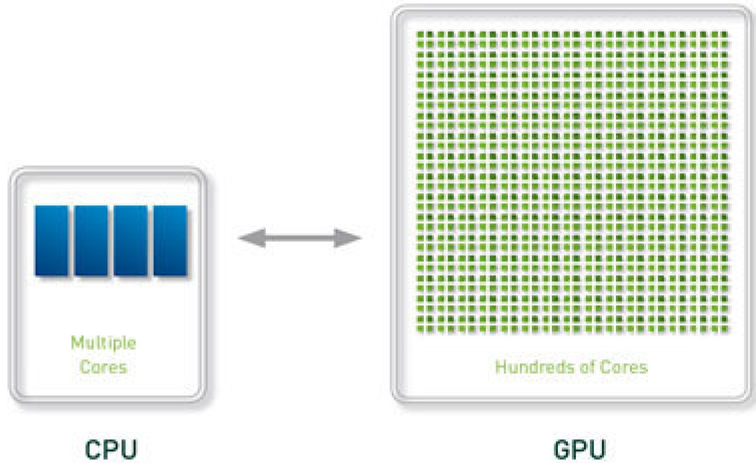
Need for the Present Work

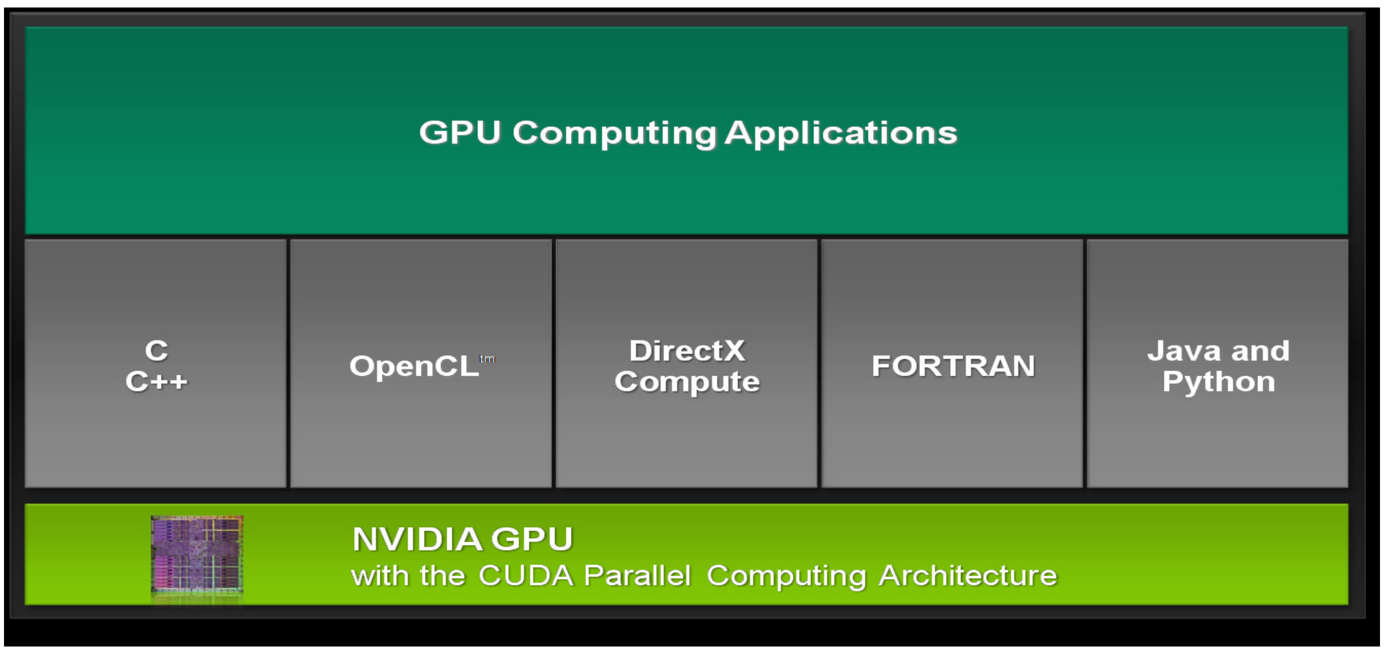
- ❖ Real-time simulation of biological organs – for surgical simulators
- ❖ Use continuum mechanics based models for better realism

Present approach to achieve the speed needed for real-time performance?

- ✓ Use the simplified material behaviour
- ✓ Perform pre-computations whenever possible
- ✓ Use a Graphics Processing Unit (GPU)

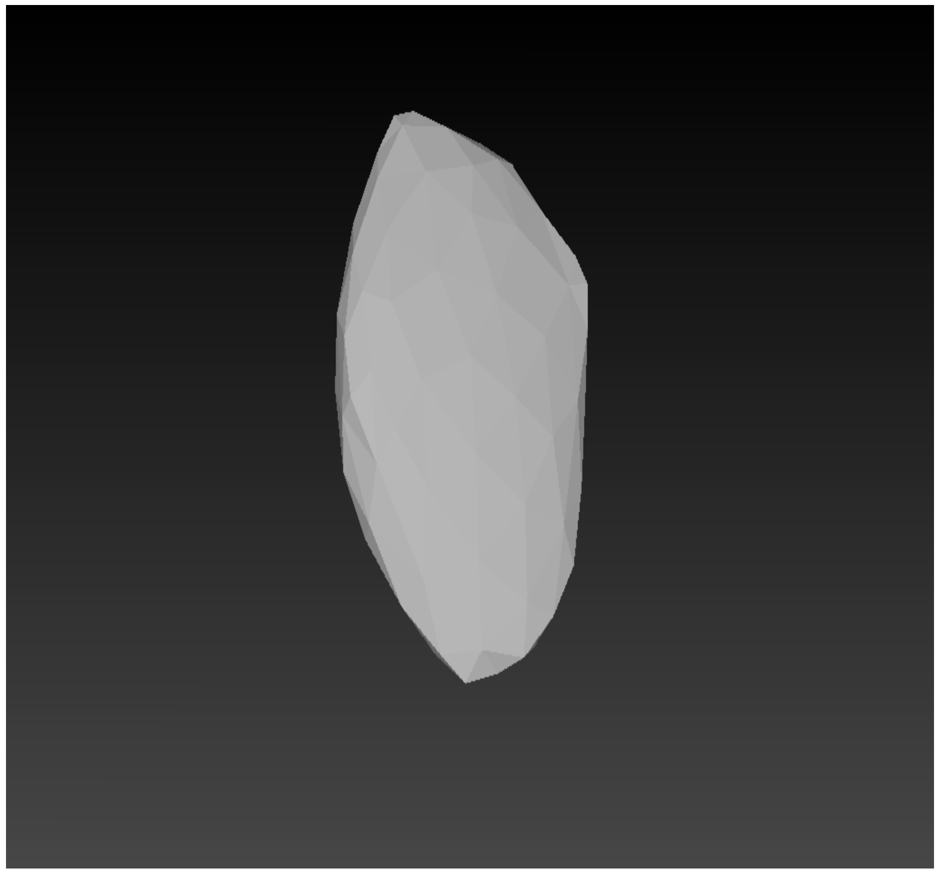
GPU (Images from www.nvidia.com)





The geometry of liver

CT-scan data is from [3], Procedure to extract the liver is from [4]



Linear Elastostatics

$$(\lambda+\mu)\left\{\frac{\partial^2 u_x}{\partial x^2}+\frac{\partial^2 u_y}{\partial x \partial y}+\frac{\partial^2 u_z}{\partial x \partial z}\right\}+\mu\left\{\frac{\partial^2 u_x}{\partial x^2}+\frac{\partial^2 u_x}{\partial y^2}+\frac{\partial^2 u_x}{\partial z^2}\right\}=0$$

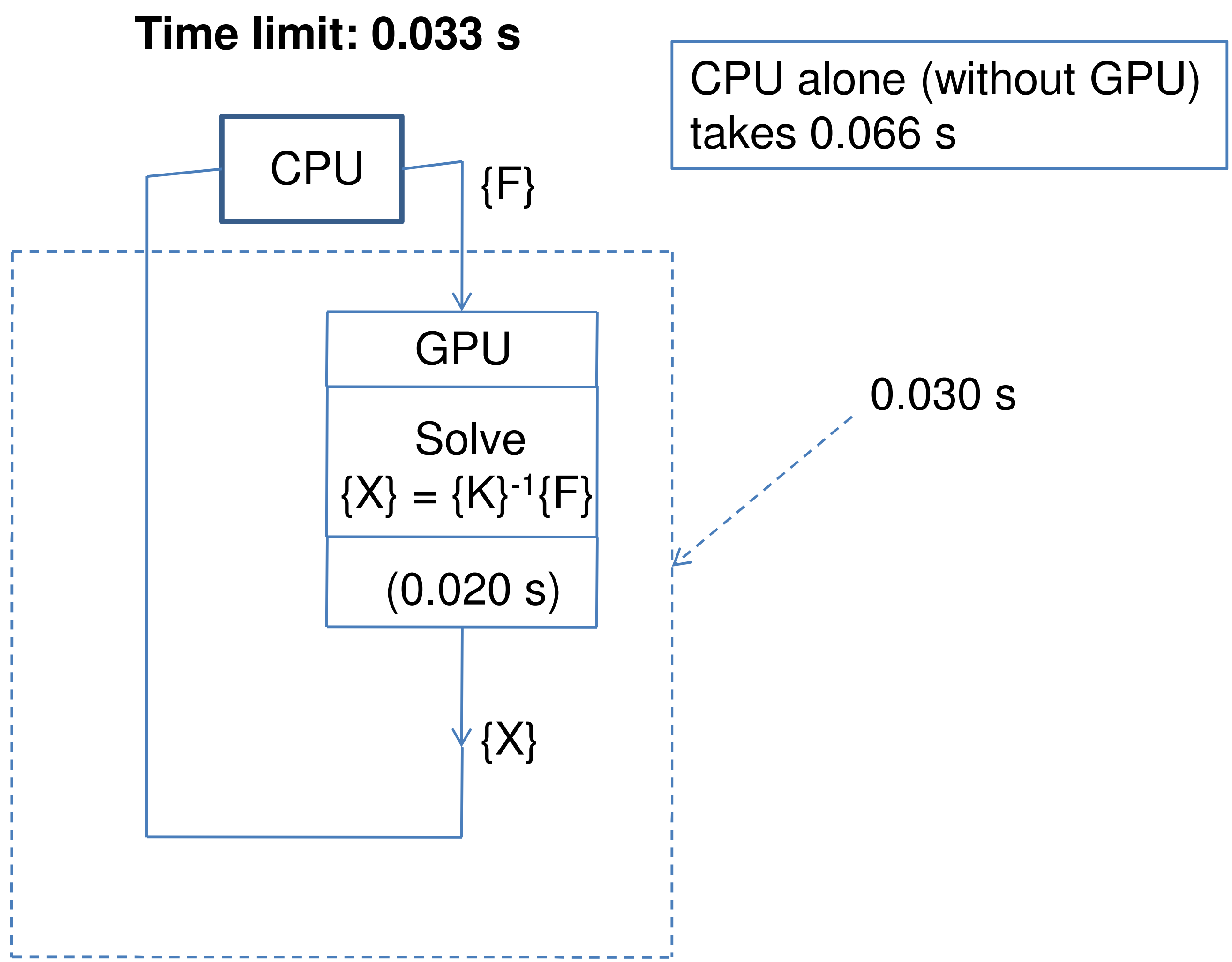
$$(\lambda+\mu)\left\{\frac{\partial^2 u_y}{\partial y^2}+\frac{\partial^2 u_x}{\partial x \partial y}+\frac{\partial^2 u_z}{\partial y \partial z}\right\}+\mu\left\{\frac{\partial^2 u_y}{\partial x^2}+\frac{\partial^2 u_y}{\partial y^2}+\frac{\partial^2 u_y}{\partial z^2}\right\}=0$$

$$(\lambda+\mu)\left\{\frac{\partial^2 u_z}{\partial z^2}+\frac{\partial^2 u_x}{\partial x \partial z}+\frac{\partial^2 u_y}{\partial y \partial z}\right\}+\mu\left\{\frac{\partial^2 u_z}{\partial x^2}+\frac{\partial^2 u_z}{\partial y^2}+\frac{\partial^2 u_z}{\partial z^2}\right\}=0$$

$$\lambda=\frac{\nu E}{(1+\nu)(1-2\nu)} \qquad \mu=\frac{E}{2(1+\nu)}$$

- Use ANSYS to get the global stiffness matrix
- ANSYS will automatically incorporate the above equations
- Discretize by 2500 nodes (size of the global stiffness matrix = 7500 by 7500)

Solution Strategy and Solution Times (GPU used: NVIDIA GeForce GTX 460)



(MATLAB and GPUmat are used for obtaining the results)

Conclusions

- CPU alone > Real-time not possible
- Real-time graphical simulation possible with GPU acceleration
- GPU > low cost & low power consumption
- Better HPC solution for laparoscopic surgery simulators

Limitations

- Rendering has not been considered
- Linear elastostatics is too basic
- Present work is only a demonstration of a concept – no implementation & validation

Future work

- Include rendering
- Consider nonlinearity
- Implement and validate the concept – develop software for a simulator capable of simulating laparoscopic surgery

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Thank You!