Implementation of OpenSource Structural Engineering Application OpenSees on GPU platform

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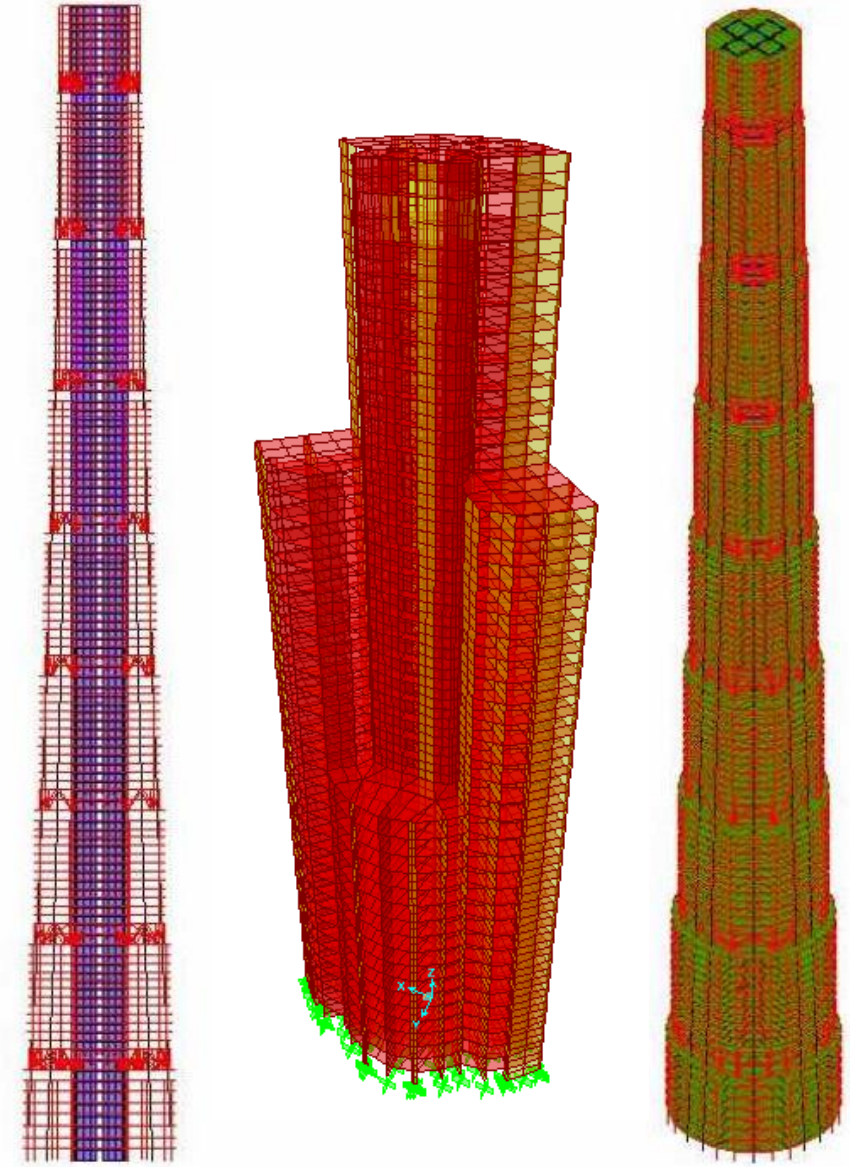
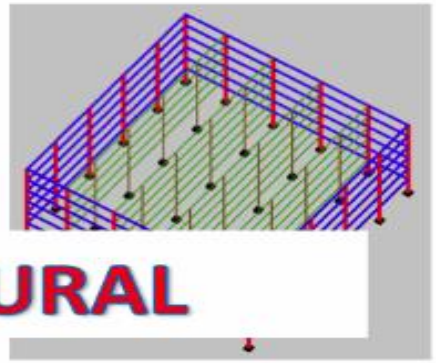


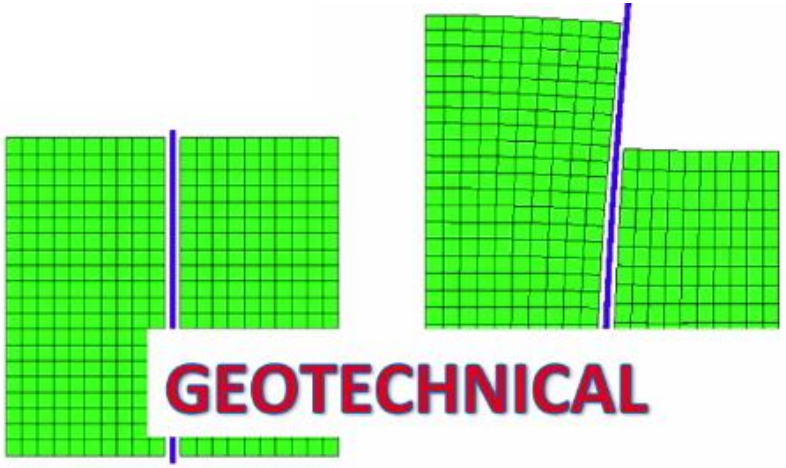
About OpenSees

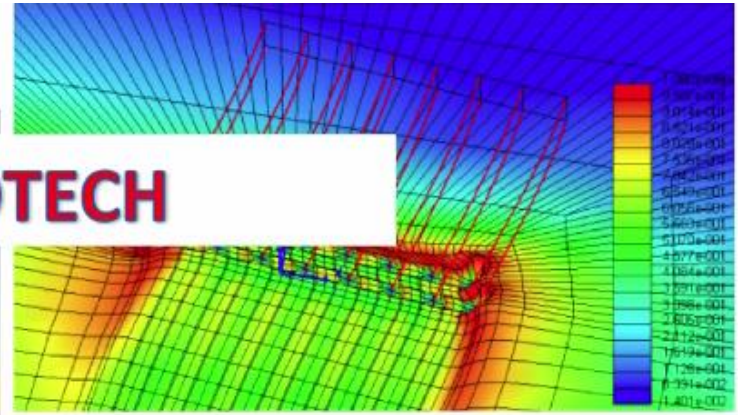
The software framework OpenSees (Open System for Earthquake Engineering Simulation) provides a platform for structural and geotechnical engineers.
OpenSees has more than 160 element types , 220 material types, 15 solution algorithms and 30 solver types

Static Problems : Deformation analyses (1D, 2D, or 3D)
Consolidation problems
Soil-structure interaction problems
Shallow foundations (e.g. bearing capacity, deformation)
Pile foundations (e.g. vertical and lateral capacity)

Dynamic (earthquake problems): Free-field analysis
Liquefaction-induced problems
Soil structure interaction problems

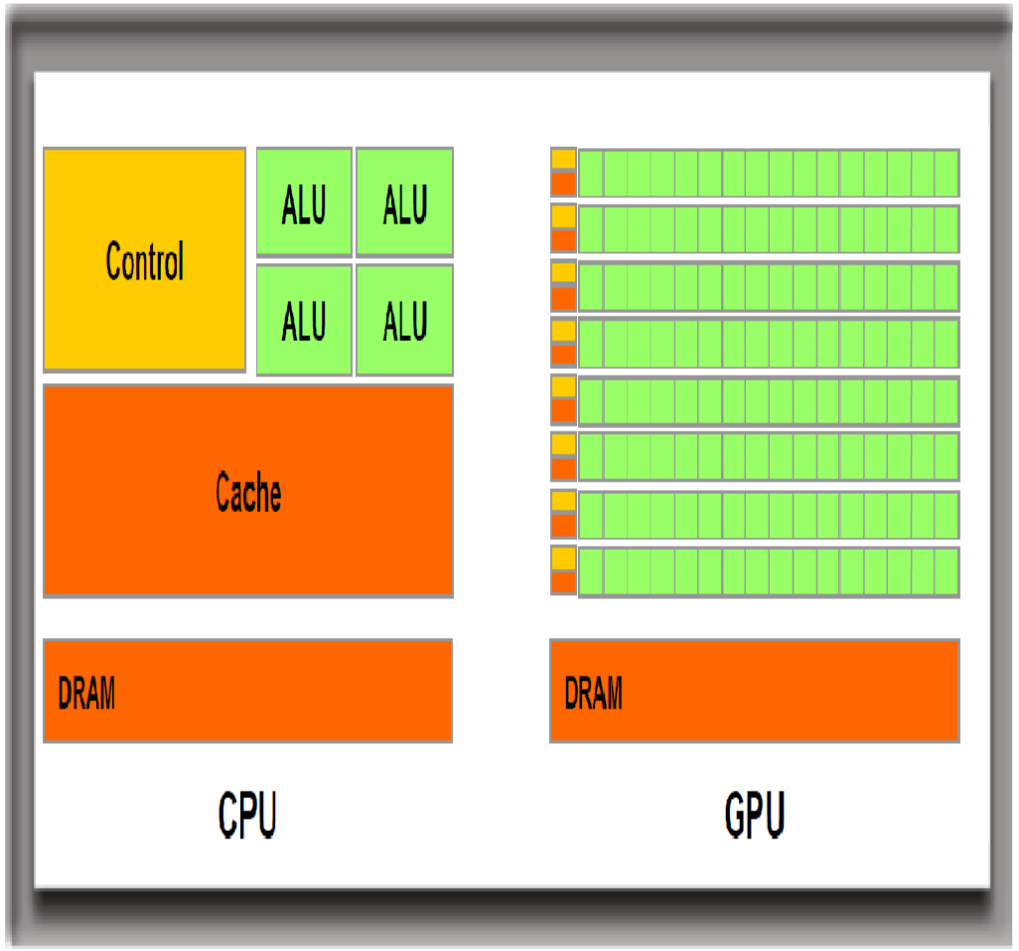






Objective of the Study

- For earthquake simulation of large scale structural and geotechnical system parallel computation is the only option.
- Algebraic libraries developed very rapidly for solving very large number mathematical problems using efficient parallel algorithms. Accelerators such as GPUs are very efficient in handling such problems.
- Available GPU enabled version of OpenSees provided by Xinzheng Lu, Linlin Xie (Tsinghua University, China) uses CulaS4 and CulaS5, which use the Cula library. Also currently supported on window's platform
- GPU computing is emerging as an alternative to CPUs for throughput oriented applications because of their Number of cores embedded on the same chip
- User friendly changes in input scripts of the application and from developers prospective great expertise in CUDA programming is not a limitation.



Source: https://goo.gl/images/Sr5sKd

Why CUSP

Libraries Considered

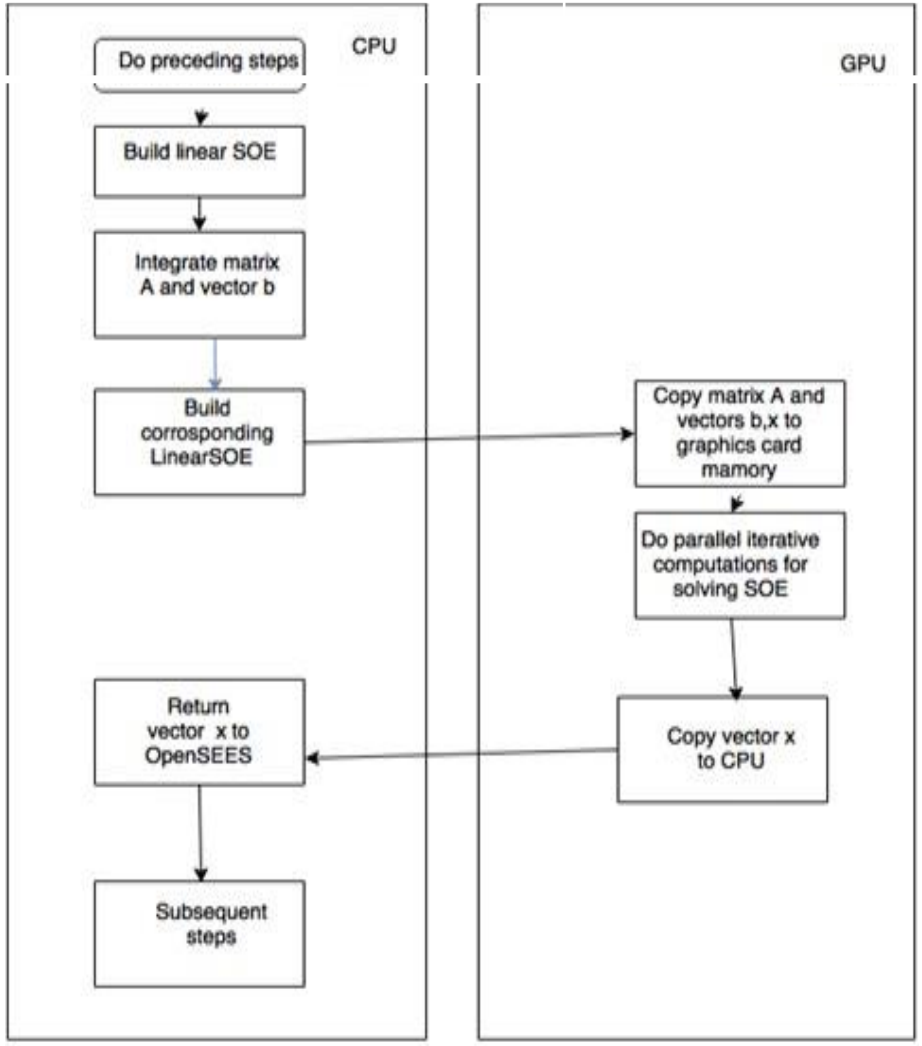
Library	Type
CULA	Licensed
CUSP	OpenSource
cuSPARSE	Closed Source
PETSc	OpenSource

Hardware Used	Software Used
One of the server of CAE group at CDAC (cfd-WS2) with following configuration used for testing and simulation. • CPU : 20 x Intel(R) Xeon(R) CPU E5-2650 v3 @ 2.30 GHZ • GPU : 2 x NVIDIA GK104GL - Quadro K4200 • RAM : 32 GB • OS : CentOS 6.7	• OpenSees 2.4 and above • gcc: 4.5.0 • make: 2.8.11 • tcl8.5 • tcl8.5-dev • g++ :4.5.0 • gfortran • CUDA 7.0 and higher • CUSP library

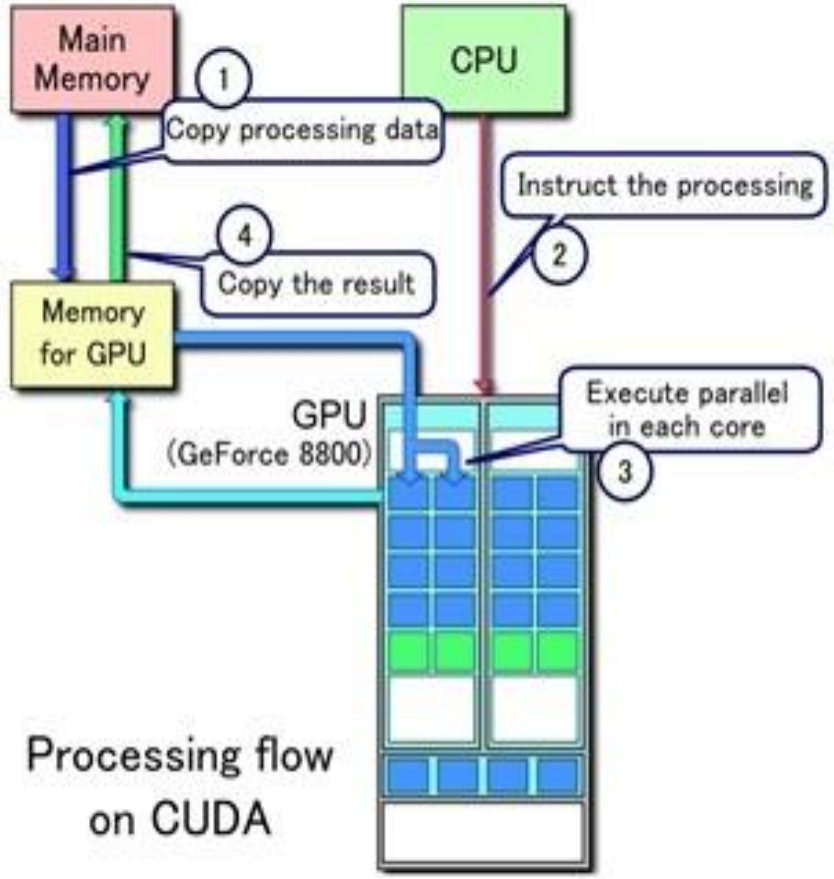
- **CuSP** provides a flexible, high-level interface for manipulating sparse matrices and solving sparse linear systems.
- It is the best suited library as it will give the interface for C and C++ classes.
- Most important, it is open Source and easy in new algorithm implementation compared to others.

Methodology

Basic Processing Flow



Example of Processing Flowchart



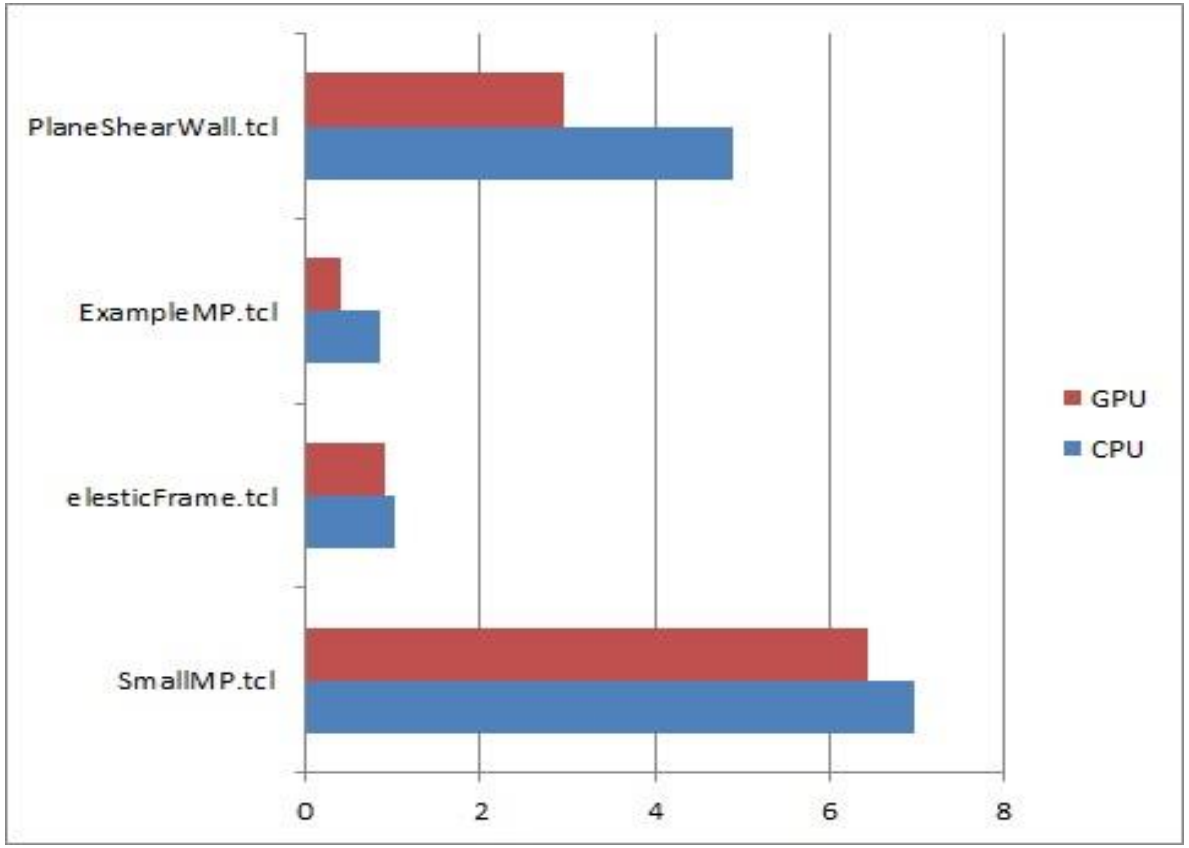
Source : https://commons.wikimedia.org/wiki/File:CUDA_processing_flow_(En).PNG

Case Study and Results

Modifications in Input Script

Input Script (CPU)	GPU enabled Script
integrator LoadControl 1.0 algorithm Linear numberer RCM constraints Plain system SparseGeneral -piv analysis Static analyze 1	integrator LoadControl 1.0 algorithm Linear numberer RCM constraints Plain system CuSP analysis Static analyze 1

Example	Run Time (min)		Speed Up
	CPU	GPU	
SmallMP.tcl	6.978	6.441	1.08
elesticFrame.tcl	1.006	0.9	1.12
ExampleMP.tcl	0.854	0.4	2.14
PlaneShearWall.tcl	4.91	2.97	1.66



GPU and CPU Performance comparison

Availability in Public Domain

opensees.berkeley.edu/WebSVN/filedetails.php?repname=OpenSees&path=%2Ftrunk%2FSRC%2Fsystem_of_eqn%2FlinearS(

Search

SUBVERSION REPOSITORIES OPENSEES

OpenSees | calm | English - English

(root)/trunk/SRC/system_of_eqn/linearSOE/sparseGEN/CuSPSolver.cpp - Rev 6505

Rev HEAD

Rev 5721 | Blame | Compare with Previous | Last modification | View Log | RSS feed

```
// Written: fmk
// modified by gourik@cdac.in (CDAC, Pune)
// nayakshweta19@gmail.com (ME student PICT,Pune)
//

#include "CuSPSolver.h"
#include <iostream>
using std::cout;

int cuspsolver(double *C, double *B, double *host_x,int size,int nnz,int *rowStartA, int *colA,int maxInteration,double relTolerance,int preCond,int solver);

CuSPSolver::CuSPSolver(void):SparseGenRowLinSolver(SOLVER_TAGS_CuSP)
{
  single=0;
```

Future Scope

- **Multi-GPU Implementation :** All above mentioned work is done for single GPU implementation. By adding the necessary support of thrust library to CuSP or by rewriting dynamic library using multi-GPU supporting CUDA enabled libraries, implementation of other accelerators mean for heterogeneous/ hybrid architecture more speed up can be achieved. Only concern will be the increase in complexity from users perspective need to be considered.

- **Adding support for OpenCL:** The provided implementation has the limitation that it can only be used with NVIDIA GPUs. Implementing support for platform independent GPU computing APIs, such as OpenCL, would therefore make the implementation accessible to more users.


Thank you!