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GPGPU Implementation of Matrix Formalism for Beam Dynamics Simulation

speaker:
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Overview

- brief description of Matrix Formalism;
- test on CPU in parallel codes;
- Matrix Formalism for beam dynamics simulation;
- survey of GPU technologies.

Matrix Formalism

is an integration method based on map building in 2-dim matrix form

$$\frac{dX(t)}{dt} = F(t, X)$$

Non-linear system of ordinary differential equations

$$P^{1k}(t) = \frac{1}{(k)!} \frac{\partial^k F(t, X_0)}{\partial (X^{[k]})^T}$$

Matrix form of ODE

Matrix Formalism

General view of equation:

$$\frac{dX(t)}{dt} = \sum_{i=1}^{k} P^{1i}(t) X^{[i]}$$

The solution of X can be found this way:

$$X(t) = \sum_{i=1}^{k} R^{1i}(t) X^{[i]}$$

Matrix Formalism

Tuesday, August 21, 14.25 pm, Salon 19, 1st Floor

The Convergence and Accuracy of the Matrix Formalism Approximation

Speaker: Prof. Serge Andrianov

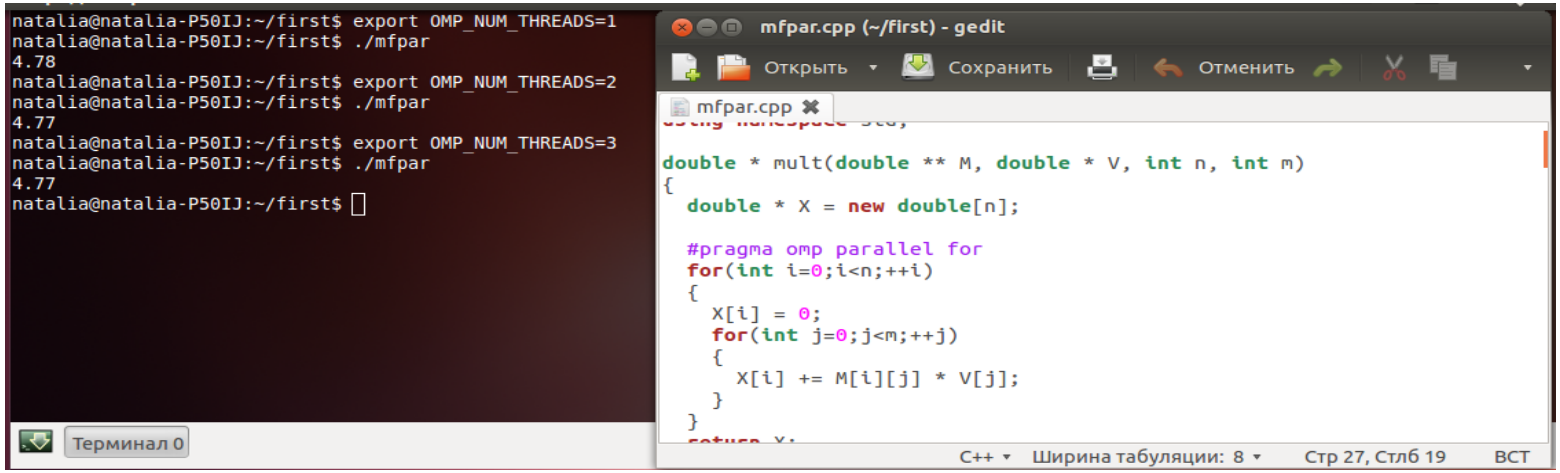
Wednesday, August 22, 14.50 pm, Ballsaal A, Ground Floor

Matrix Formalism for long-term evolution of charged particle and spin dynamics in electrostatic fields

Speaker: Andrei Ivanov

Results on CPU

Realization: program on C++



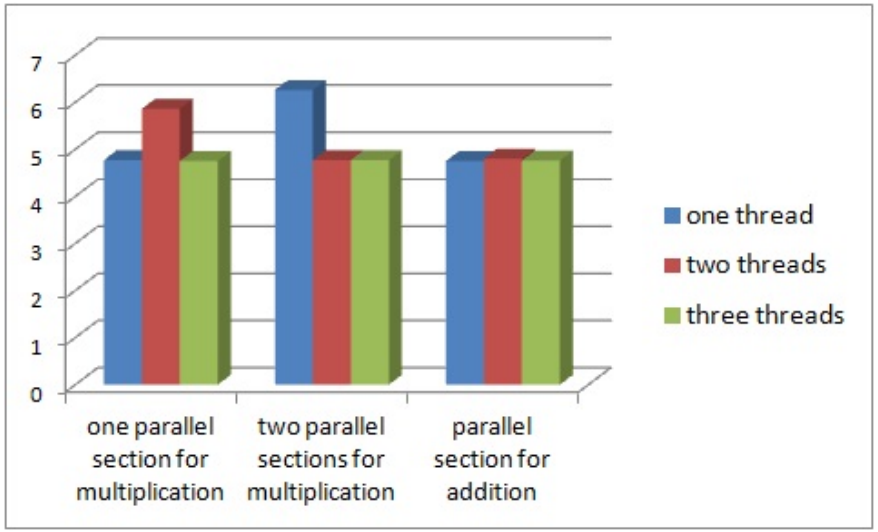
paralleling:

- multiplication (two ways);
- addition.

Results on CPU

For 1 000 000 turn we have:

	one parallel section for multiplication	two parallel sections for multiplication	parallel section for addition
one thread	4,77 sec	6,26 sec	4,75 sec
two threads	5,86 sec	4,77sec	4,8 sec
three threads	4,75 sec	4,77 sec	4,76 sec



More than three threads are not profitable

Beam dynamics simulation

Set of particles mapping

$$X = R_0 + R_1 X_0 + R_2 X_0^{[2]} + \ldots$$

CPU

$$\text{א}_0 = (X_1 \quad X_2 \quad X_3 \quad \ldots \quad X_{m0})$$

$$\text{א}_0^{[k]} = (X_1^{[k]} \quad X_2^{[k]} \quad X_3^{[k]} \quad \ldots \quad X_m^{[k]})$$

$$\text{א} = R_0 + R_1 \text{א}_0 + R_2 \text{א}_0^{[2]} + \ldots$$

GPU

Beam dynamics simulation

Envelope mapping

$$X_0^T A X_0 < 1$$

initial particle distribution

$$X = R X_0$$

where R is a linear map

$$X_0 = R_0^{-1} X$$

$$X^T \underbrace{R^{-1} A R} X < 1$$

new envelope

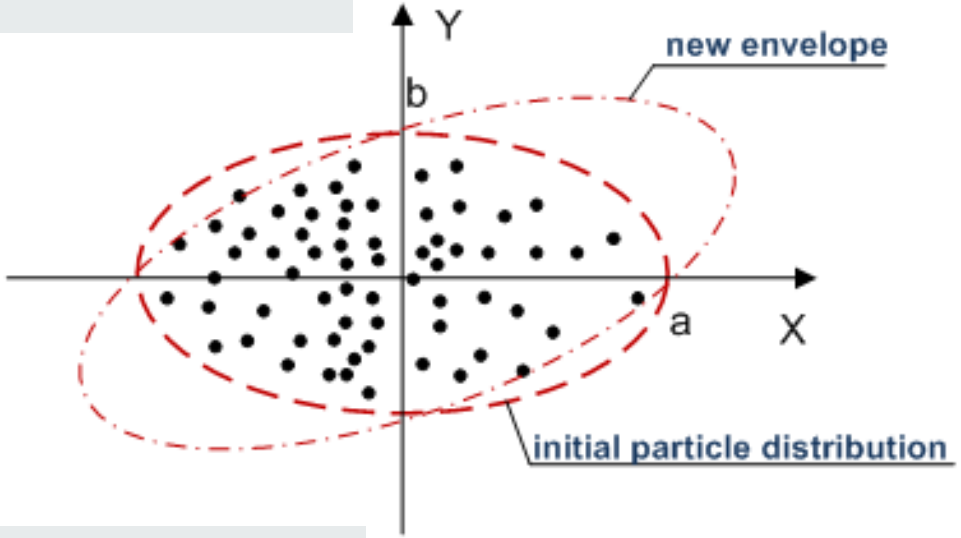
in case of non-linear map the transformations are similar

Beam dynamics simulation

Envelope mapping

$$X_0^T A X_0 < 1$$

initial particle distribution



$$X^T \underbrace{R^{-1} A R} X < 1$$

new envelope

in case of non-linear map the transformations are similar

Extension space: example of 2 order

$$\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} a_1 & a_2 \\ a_3 & a_4 \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \end{pmatrix} + \begin{pmatrix} b_1 & b_2 & b_3 \\ b_4 & b_5 & b_6 \end{pmatrix} \begin{pmatrix} x_0^2 \\ x_0 y_0 \\ y_0^2 \end{pmatrix}$$

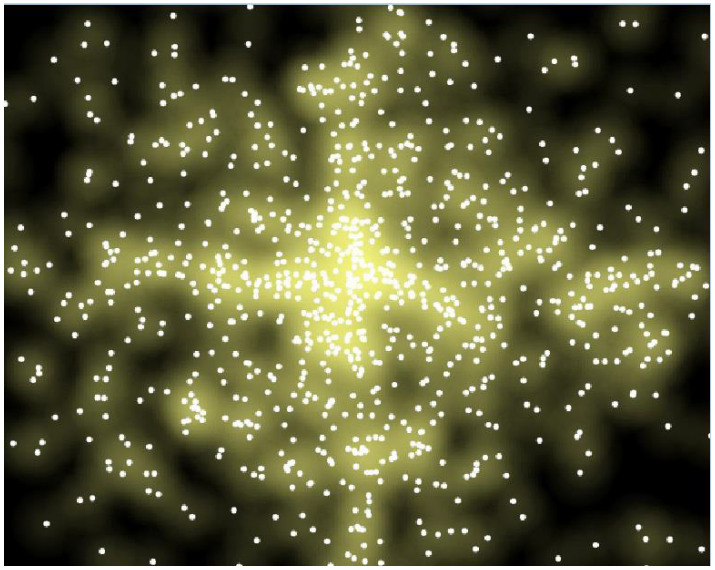
A non-linear map can be represented as linear in extension space:

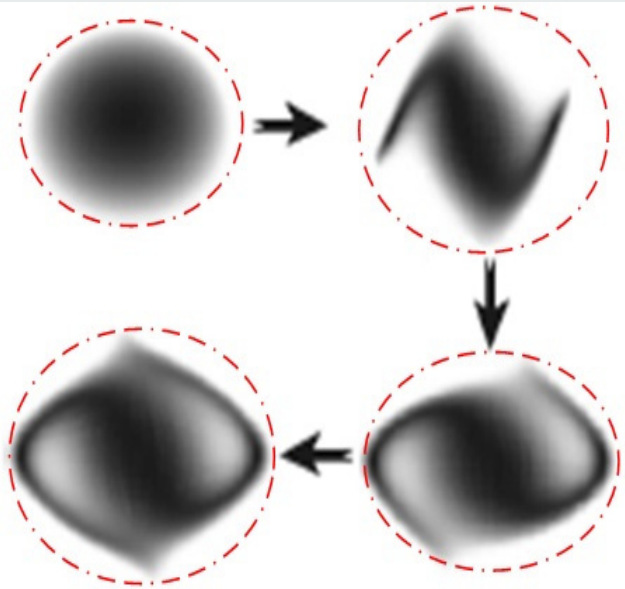
$$\begin{pmatrix} x \\ y \\ x^2 \\ xy \\ y^2 \end{pmatrix} = \begin{pmatrix} a_1 & a_2 & b_1 & b_2 & b_3 \\ a_3 & a_4 & b_4 & b_5 & b_6 \\ 0 & 0 & a_1^2 & 2a_1a_2 & \dots \\ 0 & 0 & \dots & \dots & \dots \\ 0 & 0 & \dots & \dots & \dots \end{pmatrix} \begin{pmatrix} x_0 \\ y_0 \\ x_0^2 \\ y_0 \\ y_0^2 \end{pmatrix}$$

Extension space : example of 2 order

$$X = R^{11} X_0 + R^{12} X^{[2]}$$

$$\begin{pmatrix} X \\ X^{[2]} \end{pmatrix} = \begin{pmatrix} R^{11} & R^{12} \\ 0 & R^{22} \end{pmatrix} \begin{pmatrix} X_0 \\ X_0^{[2]} \end{pmatrix}$$





Petergof Telecomunication centre

```
login as: rgusmanov
rgusmanov@v570.apmath.cc.spbu.ru's password:
Last login: Fri Jun 29 00:29:31 2012 from 195.19.253.141
[rgusmanov@v570 ~]$ source HPPBS.env
[rgusmanov@v570 ~]$ qsub -q gpu3 scharge/scharge.sh
4027.mgmt
[rgusmanov@v570 ~]$ qstat -n

mgmt:
                                                                  Req'd  Req'd   Elap
Job ID          Username Queue    Jobname    SessID NDS TSK Memory Time  S Time
--------------- -------- -------- ---------- ------ --- --- ------ ----- - -----
3993.mgmt       akarpenk gpu3     Tube3DPovo  16146   1   1    --     --  R 299:0
   tesla09/0
4021.mgmt       akorolev gpu3     run_8.sh     9230   1  12    --     --  R 31:49
   tesla12/0*12
4026.mgmt       rgusmano gpu3     scharge.sh   8257   1   1    --     --  R 00:02
   tesla09/1
4027.mgmt       rgusmano gpu3     scharge.sh  10628   1   1    --     --  R 00:00
   tesla09/2
[rgusmanov@v570 ~]$
```

CPU	Switch	Disk space	GPU	RAM node	Sum RAM	in all	Floating-point operations per second
2x Intel X5650 2,67 GHz	Infiniband 20 Gbit/c	120 GB	3x (8x) NVIDIA Tesla M2050	96 GB	2.3 TB	24 nodes , 288 kernels, 112 GPU	59,6 Tflops

Parallel Technologies

Different groups of technologies:

- using a high-level communication libraries and interfaces (API) (MPI, MPL, OOMPI, OpenMP);
- using special "parallelizing" structures in the programming language (MPC++, mpC, Ada,MC#,Cray MPP Fortran);
- using automatic parallelization of sequential programs (FORSE,PIPS, VAST, V-Ray);
- using parallelized procedures of the specialized libraries (ATLAS, PLAPACK,PIM);
- using specialized software packages (ANSYS, ABAQUS, CFX,FLOWVISION, LMS Virtual Lab., GDT).

OpenMP

The OpenMP API use the FORK/JOIN model of parallel execution:

- thread-master generates complementary threads (operation FORK is running);
- each thread has its own number, thread-master has zero number;
- all threads run the same code of the parallel environment;
- thread-master waits ending of all other threads and continues to do next step (operation JOIN is running).

Conclusion

Results

Matrix formalism is a high-performans approach for beam dynamic modeling. The method can be implemented in parallel codes on GPU. It allows simulate both long-term evolution of a set of particles, and evaluating based on envelope description.

Further development

We assume to use other parallel techniques investigation and complete implementation of the described approaches.

Acknowledgments

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Thank you for your attention