CATEGORY: COMPUTATIONAL PHYSICS - CP04

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GPU TECHNOLOGY CONFERENCE

Explore Computational Power of Mobile Platforms in Micromagnetic Simulations

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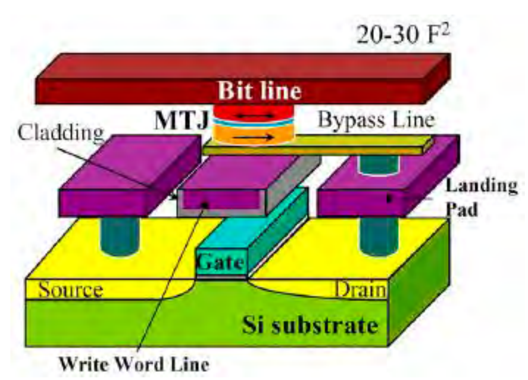
ABSTRACT

- The feasibility of using high-performance desktop and embedded mobile computation platform is presented
- Micromagnetic simulations are important tools to understand magnetic systems such as hard-drive and magnetic RAM systems
- FastMag FEM-based micromagnetic simulator is used as a test bed, showing high efficiency on several platforms
- Optimization aspects of improving the performance of the mobile systems are discussed
- The high performance, low cost, low power consumption, and rapid performance increase of the embedded mobile systems make them a promising candidate for micromagnetic simulations

Hard Drive

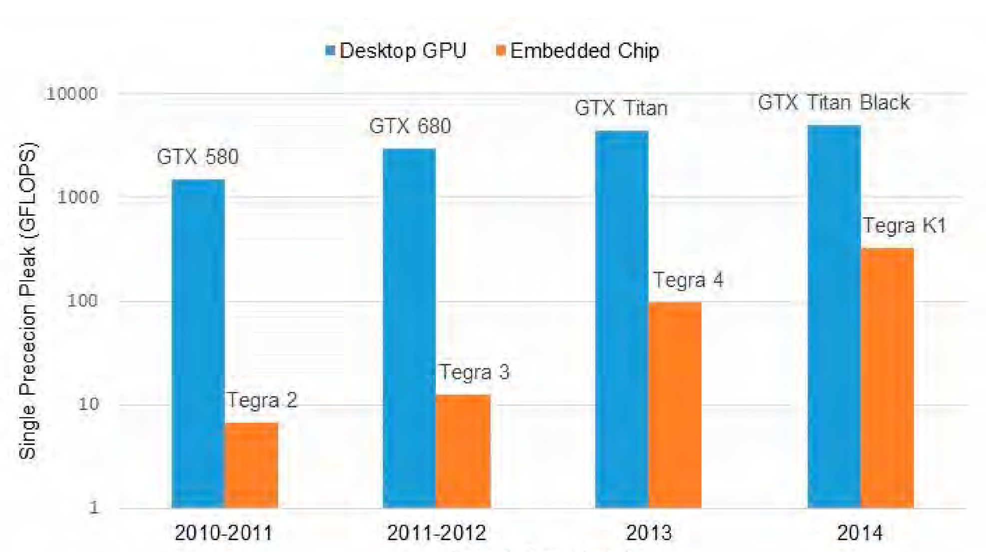
Magnetic RAM



EMBEDDED SYSTEMS AND JETSON TK1

- New embedded mobile-based computer architectures emerged
- Good performance at low power consumption and cost
- **Nvidia Jetson TK1 platform** is used as benchmarks

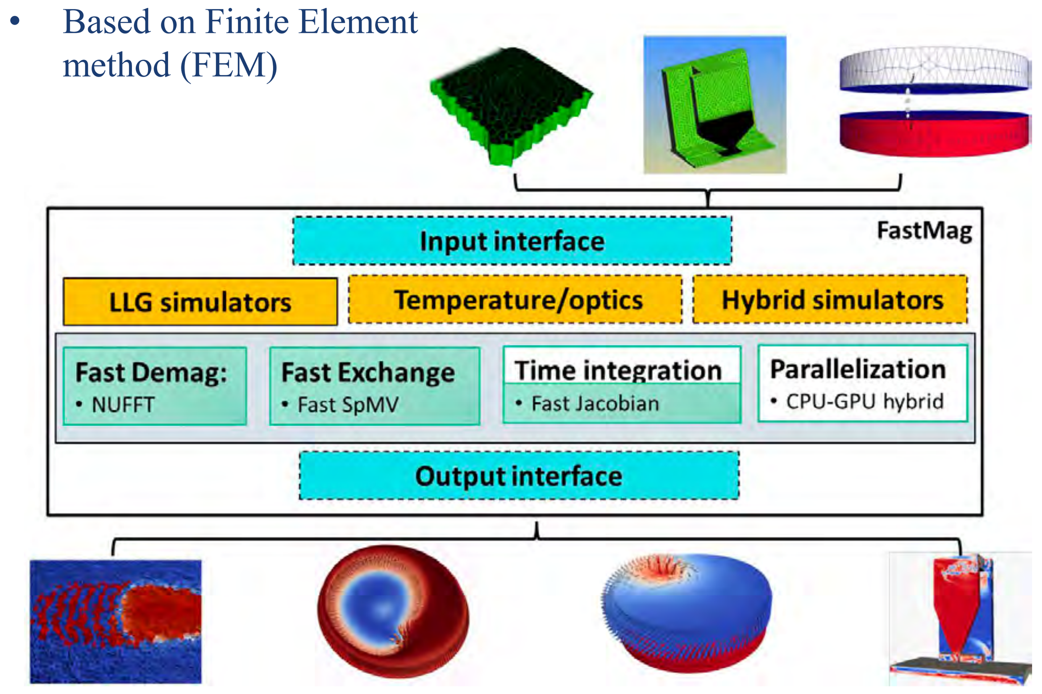
- Jetson TK1 delivers 326 GFlops at low cost ($192) and low power consumption (10w)
- Jetson TK1 is powered by Tegra K1, which sets the performance record of embedded system chips
- Performance growth of embedded GPUs outperforms that of desktop GPUs



IMPLEMENTATION

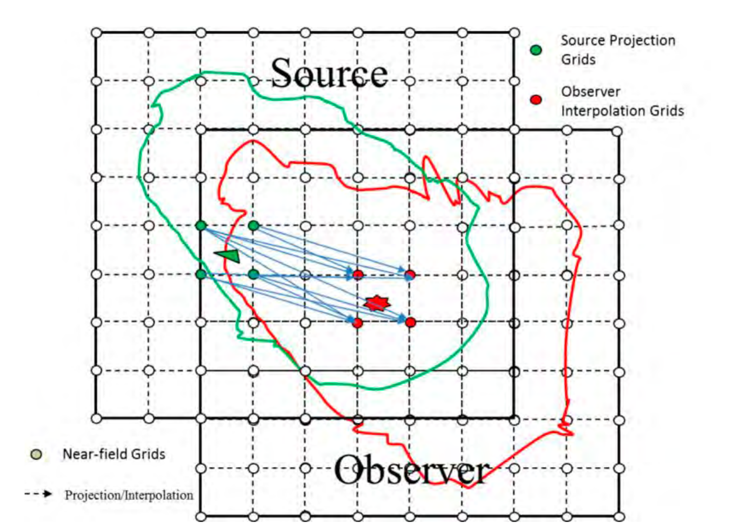
FastMag Framework

- Accelerated by **GPU**
- Based on Finite Element method (FEM)



Fast Demag: O(N²), compute intensive!

- Formulation: Superposition integrals $M_s \nabla \int \frac{\nabla \cdot \hat{\mathbf{m}}}{|\mathbf{r}-\mathbf{r}'|} dr'$
- Integral accomplished by non-uniform FFT, with cuFFT integrated



Fast Exchange

- Sparse Matrix-vector product on GPU
- Able to run on multiple GPUs

Fast Time Integration (ODE solver)

- Implicit method: Backward Differential Formula (BDF).
- Explicit method: Adams method
- Nonlinear system solved by Newton Iteration
- Linear system solved by GMRES with Jacobian. Accelerated by preconditioners
- Currently time integration in FastMag is running on CPU, while the Jacobian computation can run on GPU

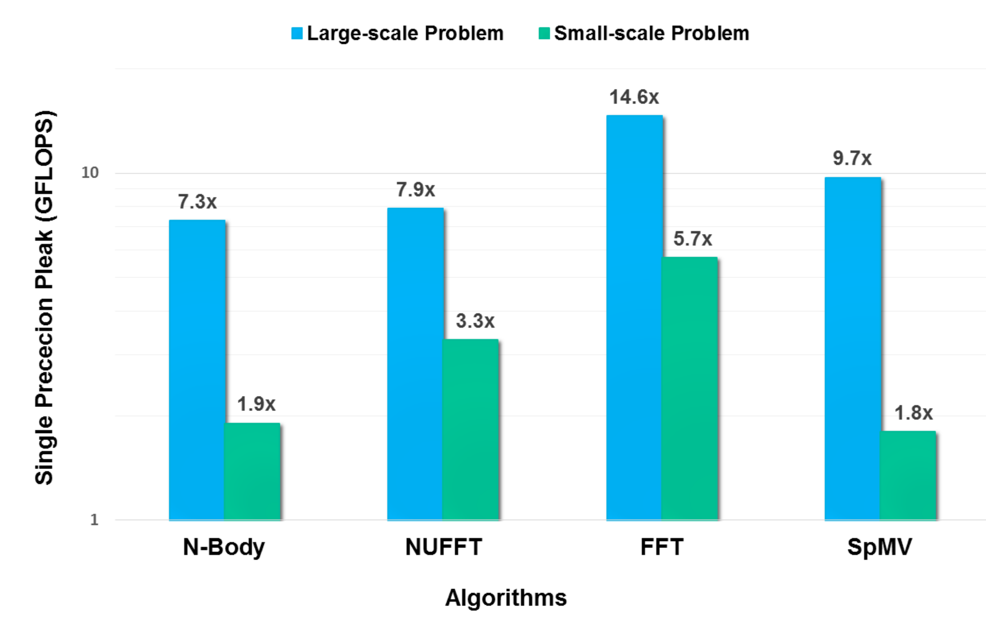
CUDA Optimization for Embedded Architecture

- Similar GPU architecture as desktop GPU, but less computing and memory resources available on embedded GPUs
- Easily importing codes from desktop to Jetson TK1
- Less shared memory and registers per core: small kernels to avoid occupancy issue
- Lower memory bandwidth: even more careful in reducing global memory traffic
- Applications that offload all computations to GPU would benefit more on Jetson Tk1 than desktop systems

RESULTS

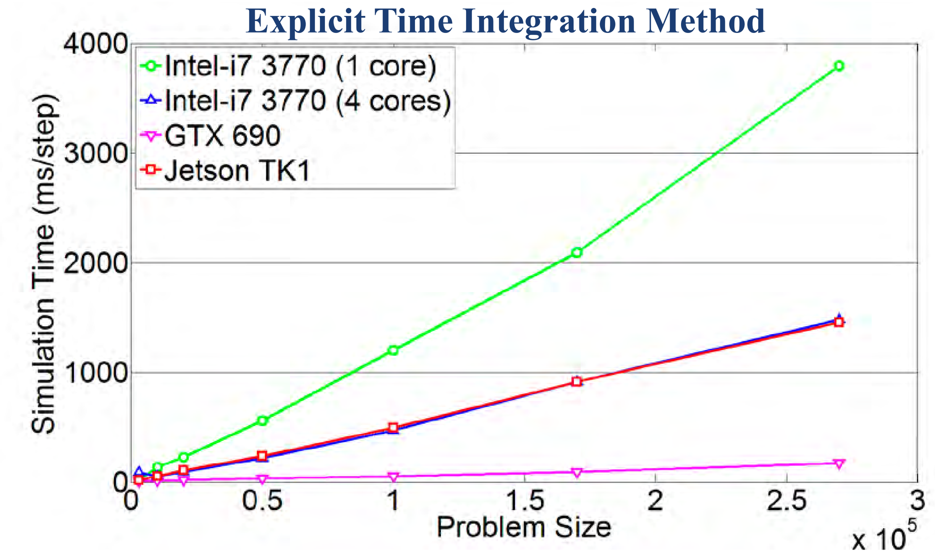
How fast is embedded GPU ?

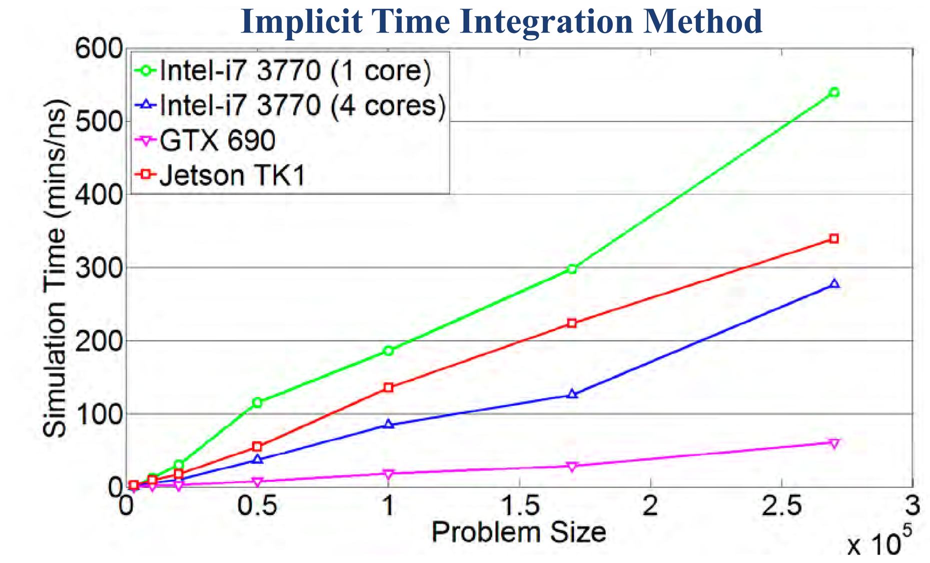
- Geforce 690 vs. Tegra K1



How fast is embedded GPUs running micromagnetic simulations?

- Tegra K1 vs. Geforce 690 vs. Intel-i7 3770
- All parallelization methods achieved good performance
  - 4 CPU cores: up to 3.1x speed-up
  - Jetson TK1: up to 2.6x speed-up
  - Desktop GPU: up to 22.1x speed-up
- Jetson TK1 vs. multi-core CPU
  - Similar performance
- Jetson TK1 vs. desktop GPU
  - 3x-9x slower
- Different performance with explicit and implicit time integration methods
  - In FastMag, larger portion of computation is running on CPU with implicit method
  - However, Tegra K1 CPU is significantly slower than desktop

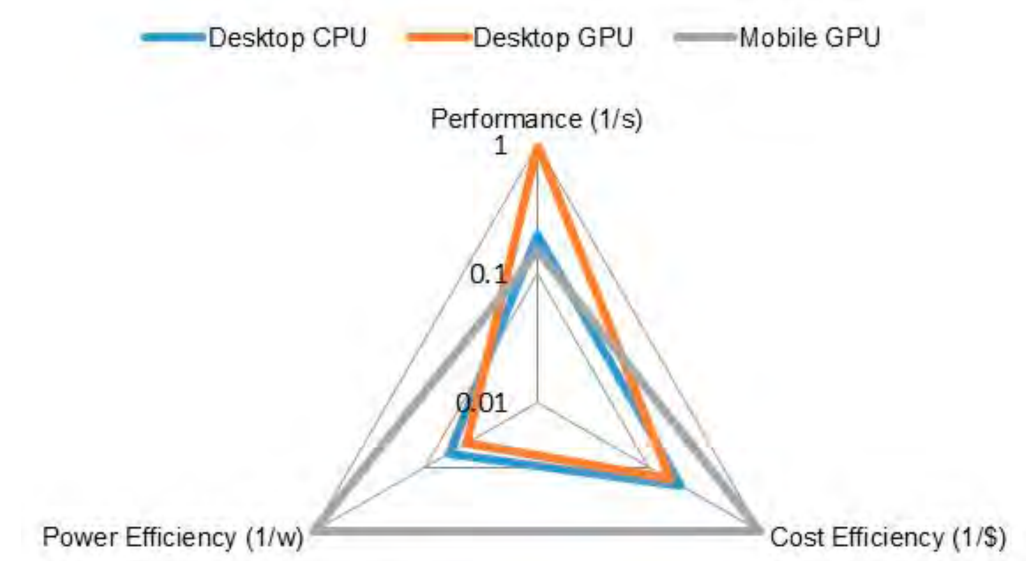




CONCLUSIONS

Embedded computing systems can be efficient for scientific computing

- Used FastMag micromagnetic simulator on Jetson TK1 as a test-bed
- Jetson TK1 vs. desktop CPU system
  - 2.6x faster than single core, similar performance to multi-core, 5x lower cost, 20x-30x lower power
- Jeston TK1 vs. desktop GPU system
  - 3x-9x slower, 10x-20x lower cost, 70x lower power



- First time demonstrating embedded mobile CPU-GPU computing architectures to run micromagnetic simulations
- FastMag simulator was used as a testbed, showing good performance on all platforms
- CPU shows good parallelization efficiency, but still limited by number of cores
- Desktop GPU shows high performance compared to all systems, but higher cost and power consumption
- The mobile embedded system Jetson TK1 platform showed an attractive operations in terms of the cost/power consumption - performance ratio
- **The performance/cost/power operation features may make the mobile platforms feasible for building low-power systems for scientific computing**

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