“Streaming” Singular Value Decomposition Algorithm

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http://www.csm.ornl.gov/Internships/rams_06/abstracts/a_wynn.pdf

Abstract

In order to maintain U.S. dominance in maritime sensing, there is a continuing need to develop innovative approaches for near real-time remote detection of underwater threats and targets. However, the complexity of the calculations that one needs to perform increases dramatically with the size of the sensor arrays being deployed, particularly in littoral environments. This in turn, results in substantial growth of the underlying computational requirements. Such a growth cannot readily be met with standard hardware, and emerging, revolutionary computing technologies need to be considered. One of the most promising advances builds upon the recent availability of multi-core devices such as the Sony-Toshiba-IBM (STI) CELL processor. This processor is inherently capable of high parallelism that can nominally result in very high performance (over 200 GFLOPS per node). Singular Value Decomposition (SVD)-based methods are at the heart of underwater threat and target detection.

Background

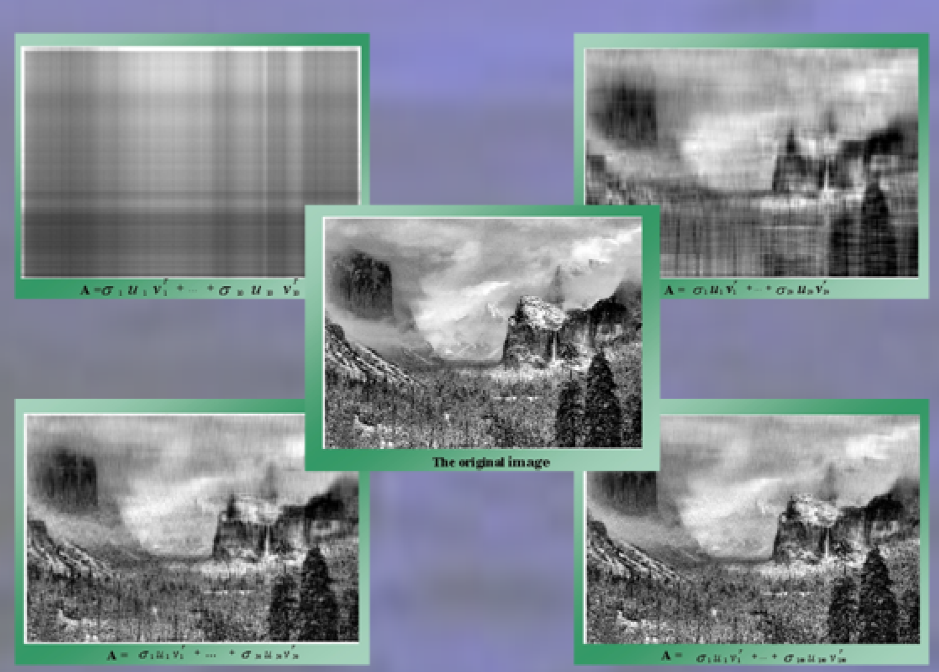

Fig1.Singular Value Decomposition (SVD

- Signal Processing challenges include high fidelity whitening of signal replicas corrupted by noise and clutter.
- SVD’s are used in signal processing to replicate an image which is effective in target and source detection.

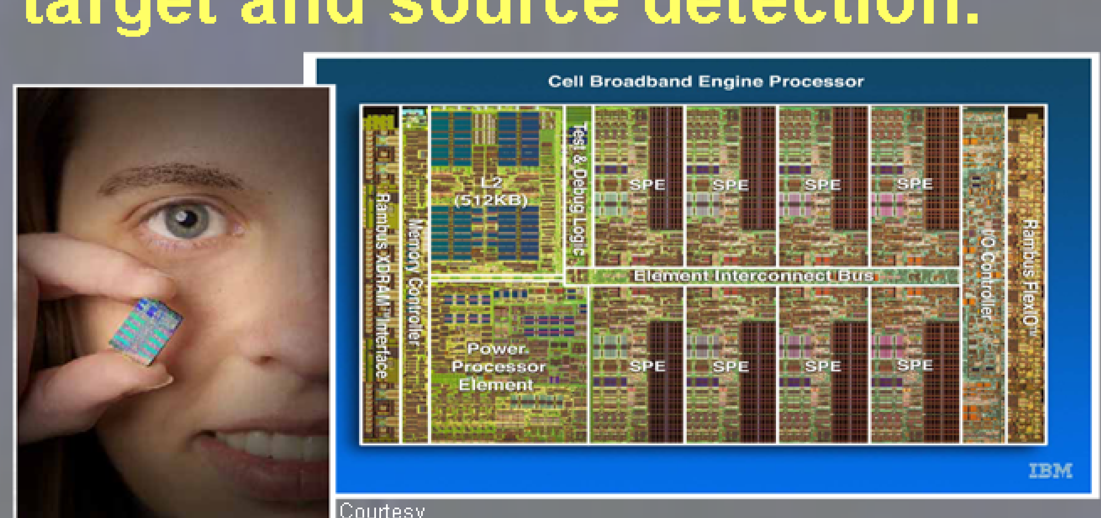

Fig 2. STI Cell

Sony-Toshiba-IBM (STI) CELL

- 200 GFLOPS per node capability
- SPE-25.6 GFLOPS 128(128-bit) registers
- PPE- L1 (32KB), L2 (512KB),
- 64-bit RISC PowerPC architecture
- Total power dissipation: 8 ◈ 4 + 30 (PPE) + EIB ~80 W

Goals

- Develop fast (streaming) Singular Value Decomposition Algorithm for complex calculations
- Implement SSVD and conventional SVD methods on STI CELL processor simulator and then on actual equipment
- Show comparative analysis with conventional methods to evaluate speed up resulting from technology and theory

“Streaming” SVD

- Fast (Streaming) SVD algorithms are needed for efficient real time signal processing.
- Computationally, SVD’s have complexity $O[m \times n \cdot \min(m,n)]$.
- “Streaming” SVD is the reduced thin SVD calculation of a rank r matrix.

$$rank(r)\left[X_{p\times q}\right] = U_{p\times r} S_{r\times r} V_{q\times r}^{\dagger}$$

- Rank 1 modifications provide the “streaming” of data as updates and down dates to the original SVD matrix.

$$X_{p\times q} + A_{p\times c} B_{q\times c}^{\dagger} = \left(\left[U_{p\times r}\ P_{p\times c}\right] U'_{p\times c}\right) S'_{r\times r} \left(\left[V_{q\times r}\ Q_{q\times c}\right] V'_{q\times c}\right)^{\dagger}$$

- A modified Gram-Schmidt algorithm is used to systematically generate the orthogonal basis for modification.

Scenario

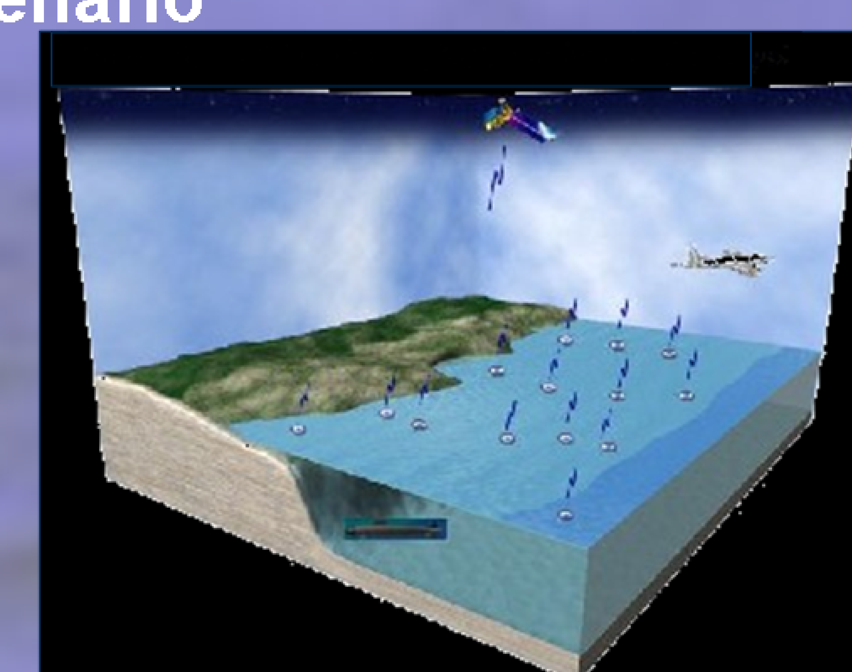

Fig 3. GPS-Capable Sonobuoys

Results

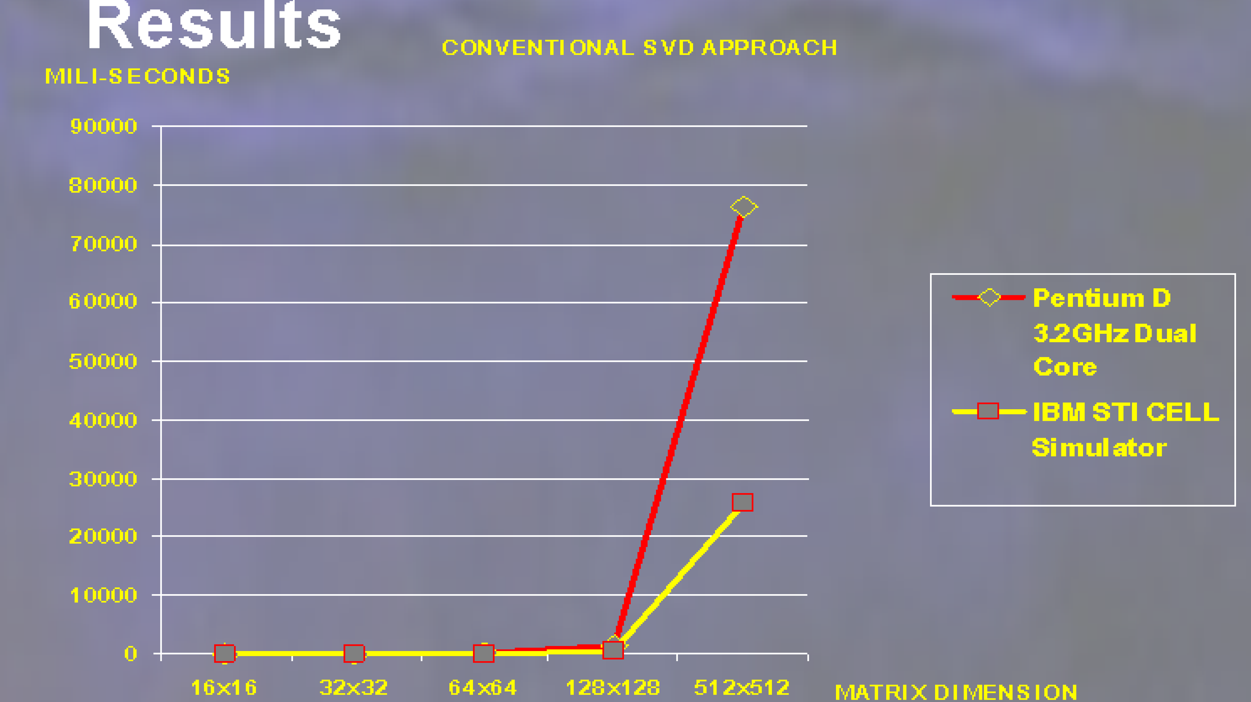

Fig 4. Data Analysis

Conclusions

- Results show speed up of large matrix calculations of the Conventional SVD on the Cell

Future Research

- Develop parallel SSVD code for optimized performance on the Cell for near real time threat and source detection

The Research Alliance in Math and Science program is sponsored by the Mathematical, Information, and Computational Sciences Division, Office of Advanced Scientific Computing Research, U.S. Department of Energy. The work was performed as part of a joint project funded by Office of Naval Research Discovery and Innovation Program, at the Oak Ridge National Laboratory which is managed by UT-Battelle, LLC under Contract No. De-AC05-00OR22725. This work has been authored by a contractor of the U.S. Government, accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes.

The author would like to thank Dr. Jacob Barhen for the opportunity to work on this project. Many thanks also go to Dr. Lawrence Marple of the Oregon State University for all of his help, source code, and direction in working with SVD’s of complex matrices. A thank you goes out to Dr. Charles Weatherford and Florida A&M University for the nurturing and scholastic support of all opportunities. Finally, special thanks go to Debbie McCoy, who made provisions for this research experience.

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