**PROBLEM**

Data production is increasing exponentially, creating a corresponding demand for Big Data processing. Complex processing with significant data interdependencies, such as graph analysis, typically requires expensive investments in hardware and software. These solutions use specialized hardware with large amounts of RAM, high-speed interconnections, and many CPUs to fit the data into memory.

**INSPIRED BY PROCESSING WITH PARALLEL SLIDING WINDOWS**

As Big Data Graphs are irregular, processing requires random access throughout the entire graph which can greatly increase processing time. Parallel Sliding Windows (PSW) is an out-of-core graph processing technique that organizes graph data into partitions to be loaded separately into memory and processed iteratively. This enables large data sets to be processed efficiently on commodity hardware.

PSW divides the graph into P Pinervals of vertices with consecutive IDs. The list of edges is then organized such that for each interval of vertices, the process only needs to access P contiguous blocks of data.

**SOLUTION**

The FUNL graph analytics solution combines the I/O efficiency of PSW, hybrid CPU/GPU algorithms, and compression techniques to deliver high performance at a much lower cost, with a low barrier to entry. Using off-the-shelf desktop hardware, FUNL performs comparably to dedicated solutions for many scenarios.

FUNL has a flexible framework that chooses the best approach to get the fastest performance for any data set and algorithm. For some scenarios, a linear algebra approach performs better than PSW. In these cases, the FUNL system divides the input matrix into smaller sub-matrices to fit into CPU or GPU memory for processing.

**FUNL vs CPU-ONLY, SINGLE MACHINE SOLUTION**

FUNL uses a GPU with 100s of compute cores to accelerate computationally intensive algorithms. The massive parallelism of GPUs speeds up analysis by as much as an order of magnitude or more, depending on the computational intensity of the algorithm as well as properties of the input data. To take full advantage of the GPU, data can be regularized for even more efficient computation. The benefit gained from the use of a GPU depends heavily on the ratio of computation to memory access. For low computation to memory access scenarios, the CPU may be more efficient. FUNL processes the data between the CPU and the GPU as necessary.

DeepInsight is a deep learning application for analyzing graph data. Based on the DeepWalk algorithm, it uses the GPU to generate many random walks on the graph in parallel, which are used to learn about relationships within the graph. The result is a compressed representation of each node that can be used for many tasks including classification and link prediction. Additionally, DeepInsight can use natural language processing to incorporate text associated with each node to improve the results.

**PERFORMANCE RESULTS**

To test performance, FUNL was evaluated against three different benchmarks:

- **Quad Core CPU benchmark**, a CPU-only solution using PSW and the same hardware as FUNL.
- **Spark cluster benchmark**, using Amazon Web Services.
- **14-Core Server benchmark**, a CPU-only solution using PSW.

**I/O EFFICIENT ALGORITHMS**

Reducing I/O is key to improving the performance of out-of-core graph algorithms.

**MASSIVE PARALLELLISM**

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**DEEP LEARNING**

DeepInsight is a deep learning application for analyzing graph data. Based on the DeepWalk algorithm, it uses the GPU to generate many random walks on the graph in parallel, which are used to learn about relationships within the graph. The result is a compressed representation of each node that can be used for many tasks including classification and link prediction. Additionally, DeepInsight can use natural language processing to incorporate text associated with each node to improve the results.

**Singular Value Decomposition** is a matrix factoring algorithm used for many applications including Principal Component Analysis. PCA uses orthogonal transformation to find a linear projection of high dimensional data into a low dimensional subspace. The resulting linearly uncorrelated variables are called principal components, and represent the dimensions in which the greatest variance in data exists.

**Belief Propagation** is a message passing algorithm performed on graph models as a method to infer information about unknown vertices based on known information about other vertices. FUNL implements BP using compressed PSW.
MISSION

The goal of FUNL is to bring meaning to data at an affordable price. FUNL incorporates commodity hardware and novel software techniques to exploit the hardware capabilities. Efficient I/O mechanisms for GPU-based graph processing, a library of graph analytic and machine learning solutions, and visualization are integrated into a unified system that provides end-to-end solutions to Big Data problems.

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