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MRI-BASED BIOMARKERS THROUGH HIGH-PERFORMANCE COMPUTING

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EXECUTIVE SUMMARY

Age-associated diseases are increasing along with the aging of the world's population. This includes diseases that affect the brain such as Alzheimer's disease (AD). AD annually costs $290 billion and contributes to more than 500,000 deaths yearly in the United States [1]. Leveraging advanced Magnetic Resonance Imaging (MRI) acquisitions and high-performance GPU-enabled computing, the research team has developed a method to investigate properties of the brain blood supply that were not previously measurable. Acquiring high-resolution MRI data of the brain while correcting for small motions of the brain during the scan delivers information on the density and microstructure of the vessels during a noninvasive MRI scan. Previously, these properties of the vessels have only been observable after death but have correlated with disease progression. The current study will enable monitoring these blood vessel characteristics over the lifespan.

RESEARCH CHALLENGE

MRI is a noninvasive, nonionizing tomographic imaging technique that enables imaging of the human brain with a variety of functional and structural contrasts, all with no more than minimal risk to the participants. For research in the basic sciences involving human subjects, MRI can measure quantities that are difficult to measure or otherwise inaccessible, such as blood flow, vascular density, and the microstructure of blood vessels in the brain. However, the MRI techniques to obtain these measures of the properties of blood vessels have lacked sufficient signal-to-noise ratio and spatial resolution to enable the monitoring of these biomarkers of health and disease. In the current work, the team leverages advanced 3D acquisitions along with a complete signal model for image reconstruction from the acquired data in order to increase the available signal and spatial resolution [2,3]. Image reconstruction can be computationally expensive for large data sets when the research team needs to incorporate compensation for physical effects in the MRI scanner along with motion of the brain during data acquisition. This can result in reconstruction times of a month or more per data set when using a single workstation, severely limiting application of these techniques.

METHODS & CODES

The team uses a GPU-accelerated image reconstruction package called PowerGrid [4] to implement 3D, field-corrected, non-Cartesian image reconstruction with nonlinear motion correction. To speed the algorithm, the researchers use GPUs to achieve high performance via OpenACC. Specifically, the team uses an implementation of the nonuniform Fast Fourier Transform (NUFFT) [5] that has been GPU-accelerated via OpenACC.

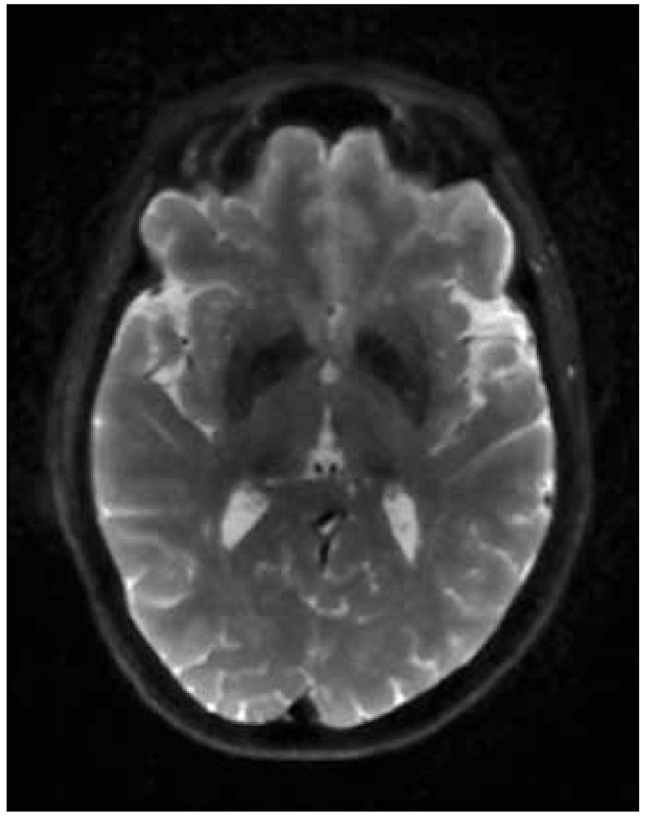

Figure 1: Example of validation image set used to test performance and accuracy between CPU and GPU parallelization via OpenACC.

RESULTS & IMPACT

The use of OpenACC on a high-performance computing platform such as Blue Waters is not without its challenges, and the interoperability of packages and compilers needs to be addressed to more efficiently leverage the large number of GPU nodes. However, large data sets such as the one in this project are not feasible to reconstruct without utilizing massive multicore strategies. The team focused on increasing the multicore utilization for NUFFT, which is the main kernel in their code, expanding the portable parallelization to use either CPUs or GPUs depending on the environment. With only one hardware-specific library (that handles efficient Cartesian FFTs), researchers can swap CPUs or GPUs for these libraries using the latest OpenACC-capable compilers. This enables transitions to future computing platforms and more widespread adoption of this approach by enabling the code to perform either on hardware accelerators or CPU cores.

WHY BLUE WATERS

Blue Waters provides an ideal environment for the highly parallel task of image reconstruction in MRI. Each participant's data requires reconstruction of many images, each with a different image contrast reflecting different properties of the brain blood flow. Utilizing multiple GPUs enables the acceleration of each image's reconstruction and the availability of a large number of GPU-enabled nodes allows the simultaneous reconstruction of all the images from several subjects' data.