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Achieving Voxel Rendering Effects using World-Class GPUs and CPUs

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Project Title

Achieving Voxel Rendering Effects using World-Class GPUs and CPUs

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I. Project Description

In this section, a short description of the project (essentially, what was advertised) is given first. Then, additional details are described. (Tone is thus more casual at the start.)

UAH will soon have a world-class computing resource equipped with thousands of computing cores and tens of thousands of graphics cores. In this project, we want to develop next-generation schemes for creating science and engineering renderings (2D or 3D visualizations) that are suitable for and can run on this world-class resource. Those schemes will encompass the use of volume representations (e.g., voxels), which you might have seen examples of in video games like Minecraft or Outcast. medium.com claims that “voxels are the future of video games, VR, and simulating reality”—and voxels are also the present and future for lots of science and engineering based discovery of new information and for guiding key decision-making. If all this sounds interesting to you, this project could be a good one for you for a summer research experience! This project involves designing and implementing computer code. You’ll also spend some time learning about new techniques, technologies, and representations that enable the development we want to do, which will enable the next generation of knowledge and information discovery!

The world-class computer comes to UAH via an NSF infrastructure grant to a team including this proposal’s mentor (Newman). Newman, with past collaborators, has previously created a series of computationally fast approaches to voxel-based rendering (VBR). Each such series focused on a mode of VBR (known as Marching Cubes (MC)) for one style of computation. For example, fast MC operation for Cray-style computing (which, in essence, simultaneously applies one common operation to a collection of values) was one focus. For each addressed style, the efforts of this proposal’s PI yielded fast (best-in-class at the time) computation for MC via careful organization and staging of data and computation and via innovative data-handling schemes. The new machine coming to UAH presents a new opportunity to deliver even higher performance for VBR in science and engineering provided that new computational and data staging and organization schemes for it are developed; such will be this RCEU’s focus.

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties: The selected undergraduate (UG) will first learn MC’s basics, in part via study of the mentor’s highly-cited survey of MC’s development. The UG will also learn about the new UAH machine’s features and about past efforts to achieve fast VBR. The UG will also complete a series of training tasks about the programming technologies that allow exploiting that machine’s computational capabilities. Next, the UG will, with the mentor, identify a series of potential computational and data staging schemes that may be exploitable for the achievement of high performance for MC on the machine. In the last third of the time, the most promising of those will be reduced to practice and their performance evaluated.
b. **Tangible Contributions by the Student to the Project (10% of Review):** The mentor previously utilized NSF funding for UGs to explore schemes enabling fast MC using first-generation streaming media capabilities on PCs. Such research yielded a paper including UG co-authors. Work here has comparable potential; the topic is approachable by UGs. Additional contributions include the computational and data staging schemes and their reduction to practice.

c. **Specific Outcomes Provided by the Project to the Student (30% of Review):** VBR schemes are growing in applicability, as stated earlier. Thus, one working on this project will gain experience in (and help set baselines for) what will likely be one of the next decade’s state-of-the-art areas for rendering (e.g., in computer-based training and the Metaverse/Virtual Reality). Specific software technologies to be used in this effort include the popular CUDA, MPI, and pthreads environments, as well as OpenGL, providing the UG participant experiences that will both broaden and deepen capabilities as a software practitioner. Lastly, the project’s performance evaluation component will expose the UG to an aspect of lab-type testing that Computer Science (CS) courses contain little of; an experimentalist perspective will be gained.

### III. Student Selection Criteria

The selected student must be proficient in C/C++ programming and have good familiarity with computing data structures (arrays, queues, stacks, and trees).

### IV. Project Mentorship (30% of Review)

The project will begin with an organizational (org) session in which the UG and mentor will detail the effort phases stated above (§II.a) via setting targets for each phase’s completion, with each phase broken down into weekly effort units. Each week, the UG and mentor will meet to discuss progress and challenges, although in week one, the mentor will meet the UG at least once daily to promote a strong start, and in weeks two and three, the mentor will meet the student thrice weekly. The student will be assigned space in the mentor’s dedicated area, with the org session and weekly meetings also conducted there. (The mentor’s graduate students (and some students of another faculty member) are currently assigned there, providing the potential of more immediate guidance throughout the project.) The mentor will also drop in at irregular intervals to enable early resolution of challenges. Early stages of the effort by the student likely will require some supplemental training in voxel-based techniques and in software environments, provided, if necessary, by several training sessions in the first weeks of the project. Certain specialized orientations (e.g., re: OpenGL and CUDA), are envisioned to be provided by students of the mentor who have worked extensively with those. Introduction of the selected student to those individuals will be achieved at a lunch sponsored by the mentor. The schemes identified here for mentorship are akin to ones used by the mentor with the successful UGs on his 2004-era project.