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Uncovering the real dirt on granular flow

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(PhysOrg.com) -- A handful of sand contains countless grains, which interact with each other via friction and impact forces as they slip through your fingers. When a handful becomes a load in an excavator bucket, those interactions multiply exponentially.

By solving large sets of differential equations, researchers can predict how sand or other granular material will move. Assistant Professor Dan Negrut and his team at the UW-Madison Simulation-Based Engineering Laboratory are developing innovative computer simulation methods for parallel computers to analyze granular material motion much faster than is possible with current technologies.

Even a supercomputer takes days to run a simulation charting the motion of millions of sand grains. Negrut hopes his simulation will analyze millions of grains in a single day, if not a matter of hours. The difference lies in how parallel computers approach the task. The central processing unit of a regular computer processes information sequentially, so grains are analyzed one after another. Parallel computers that rely on the graphics-processing unit (GPU) can simultaneously execute one instruction multiple times. This is how a graphics card processes pixels to render scene after scene in video games.

Negrut uses GPU computation to determine in-parallel sand movement. He and his students built a custom computer that handles almost 50,000 parallel computational threads at any given time. Currently, the team is working on detecting which particles collide with each other when, for example, granular material is scooped up by an excavator or driven over by a car.

"The task is challenging because there are hundreds of thousands of collisions you have to track," Negrut says, adding the preliminary data on collision detection developed by graduate students Toby Heyn and Justin Madsen look promising.

Once Negrut and his students can accurately predict collisions between individual particles, they will determine what frictional contact force is actually at work between the particles. For this, they will collaborate with Professor Alessandro Tasora from the University of Parma, Italy. Heyn is traveling to Italy this January, and Tasora will visit the team in Madison next year. (Tasora visited Negrut in February.)

"Right now we're expanding the type of problems and size of problems you can solve with a simulation," says Heyn. "Simulation is important because it's often faster and cheaper than experimental testing."

Simulations of granular flow dynamics could be particularly useful for vehicle design. The team has worked with P&H Mining Equipment in Milwaukee, which builds three-million-pound electric shovels to dig in the oil sands near Alberta, Canada. Negrut's simulations may help the company develop optimal designs for its equipment in a cost-efficient manner.

"You can change the parameters of a design easily and then quickly run a computer simulation to understand how the design change is impacting the overall performance of the computer model," says Heyn.

In addition to construction equipment, Negrut's simulations could lead to improved design of tire treads for vehicles that drive on mostly sand or dirt roads. Beyond vehicle applications, researchers could use such simulations to study atomic particles, pebble-bed nuclear reactors, pressure in silos, and crystals in prescription pills. The National Science Foundation and U.S. Army subcontracts support Negrut's work, and NVIDIA Corp., a GPU manufacturer, is also a sponsor. Recently, P&H Mining has offered additional funding.

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