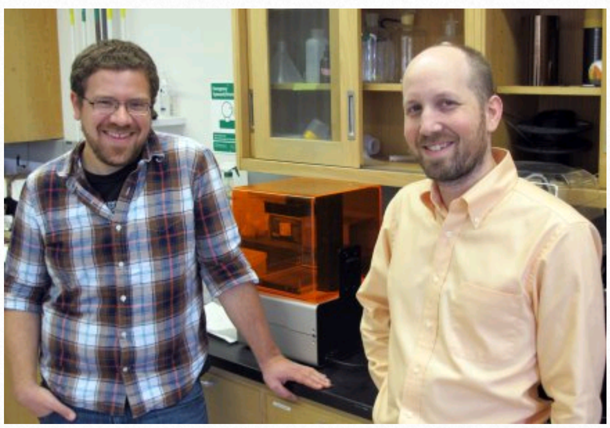
Oregon physicists use geometry to understand 'jamming' process

EUGENE, Ore. — (March 20, 2014) — University of Oregon physicists using a supercomputer and mathematically rich formulas have captured fundamental insights about what happens when objects moving freely jam to a standstill.



Their approach captures jamming — the point at which objects come together too tightly to move — by identifying geometric signatures. The payoff, while likely far down the road, could be a roadmap to preventing overfilled conveyor belts from stopping in factories, separating oil deposits trapped in sand, or allowing for the rapid, efficient transfer of mass quantities of data packets on the Internet, say UO doctoral student Peter K. Morse and physics professor Eric

I. Corwin.

Their paper "Geometric Signatures of Jamming in the Mechanical Vacuum" is online ahead of print in the journal Physical Review Letters.

"The history of the field has been looking at mechanical properties really close to the jamming transition, right where a sand pile starts to push back," said Corwin, whose research is supported by a National Science Foundation Faculty Early Career Development award. "What we're doing that is really different is we're asking what happens before the sand pile starts to push back. When it's not pushing back, you can't get any information about its mechanical properties. So, instead, we're looking at the geometry — where particles are in relation to one another."

The problem, Corwin said, involves an ages-old question used to introduce physics in early education: Is sand a liquid, a solid or a gas? "Make a sand pile, step back and it holds its shape, so clearly it's a solid," he said. "But I can take that same sand and pour it into a bucket; it flows in and takes the shape of the container and has a level surface, so clearly sand is a liquid. Or I can put a top on the bucket and shake it around really hard, and when I do that the sand fills all of the space. Clearly sand is a gas. Except, it's none of those things.

"This has led to granular materials, or little chunks of things, being referred to as a fourth state of matter," he continued. "Is sand something else? One thing everyone agrees on — the one feature about sand or piles of gravel or piles of glass spheres or ball bearings, that makes them really unique — is that when spread out they can't support any load. If you keep compressing them, and they get denser and denser, you reach a density where it's like flipping a switch. All of a sudden they can support a load."

The key, the researchers said, is identifying the nearest neighbors of particles. This is done using the Voronoi construction, a method of dividing spaces into a number of regions that was devised by Georgy Feodosevich Voronoy, a Russian mathematician in the late 19th century.

"Imagine a cluster of islands in the ocean," Morse said. "If you found yourself dropped in the water you would swim to the nearest island. You could say that the island 'owns' the region of ocean closest to it and islands that 'own' adjacent patches of ocean are nearest neighbors. We use this to characterize the internal geometry of a sand pile."

To study what happens to this internal geometry as a sand pile is compressed, they entered data into the UO's new ACISS (Applied Computational Instrument for Scientific Synthesis) supercomputer, applying the Voronoi construction.

"Using these cells, called Voronoi tesslations, you can find out all you want to know about a geometric object — its volume, surface area, number of sides — you get it all," said Morse, who also is a fellow of the UO's GK-12 Science Outreach Program that links chemistry and physics graduate students with the state's elementary and middle schools. "All of the geometric features that we can think of so far show us that systems below jamming are very different than systems that are about to jam or that are jammed already. We end up finding that this purely geometric construct will exhibit this phase transition."

And by carrying out their computations into multidimensional spaces — up to the eighth dimension in this project — researchers learned that the physics of the jamming process can be simply identified by seeing what happens in the transition from 2-D to 3-D spaces. It's at that level, applying the knowledge to high-dimensional spaces, Corwin said, that application to expanding data transfer capabilities come into focus.

"The new ACISS supercomputer puts the UO at the forefront of a revolution that applies cloud computing to scientific investigation in physics, biology, chemistry, human brain science and computer science," said Kimberly Andrews Espy, vice president for research and innovation and dean of the UO Graduate School. "By incorporating the powerful ACISS computer into this project, Dr. Corwin and his team were able to examine the geometry of jamming and provide a new perspective on the process that has potential applications down the road for everything from manufacturing to computing to power production."

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Additional Links:

Corwin faculty page:

http://physics.uoregon.edu/profile/ecorwin/

GK-12 Science Outreach Program:

http://materialscience.uoregon.edu/GK12/Overview.html

UO Physics Department:

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