Machine learning can help us predict landslides caused by climate change

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Christoph Mertz, the principal project scientist at Carnegie Mellon University's Robotics Institute, started taking pictures of the hills overlooking Pittsburgh's West End on his smartphone.

"Every day, for months, I was collecting images of these hillsides," Mertz said. "I wanted to see if I could use these pictures as a way to predict the next landslide."

Landslides are natural phenomena, but many of the conditions that can increase their likelihood are caused by human activity, such as directing surface runoff to an area or altering natural slopes for the construction of buildings and roads. Combined with increased rainfall rates related to climate change, landslides in the United States have become more common and more severe. The United States Geological Survey estimates that each year between 25 and 50 deaths are due to landslides, as well as between $2 billion and $4 billion in annual losses due to property damage. As these conditions worsen, these figures are expected to increase.

For Mertz, Pittsburgh was a prime location for this work. In 2018, Allegheny County experienced an unprecedented number of landslides, resulting in damage to at least 131 properties. By the end of the year, PennDOT estimated that the cost to fix all of the county's landslide-related damage was about $40 million. Not only does this amount look daunting, it seems wholly unanticipated. Last year, the City of Pittsburgh exceeded its allotted $1 million annual landslide remediation budget in just a few months. However, according to Karen Lightman, executive director of Metro21: Smart Cities Institute, 2018 wasn't an outlier—it's the new normal.

"The issue is that many areas are becoming wetter," Lightman said. "This problem is only going to get worse over time."

Pittsburgh isn't the only city feeling these effects. Take the case of Big Sur. In May of 2017, a landslide buried a quarter-mile stretch of California's scenic Highway 1 beneath six million tons of dirt. While no one was harmed, the landslide cut off the only northern route into Big Sur. Happening just before Memorial Day Weekend, that landslide had a significant impact on the local economy.

Four months later, the California Department of Transportation announced a plan to build a replacement road over the landslide. After $54 million and 14 months of construction to rebuild the road, a different section of Highway 1 was closed by another landslide in March.

Mertz is no stranger to finding innovative ways to anticipate infrastructural decay. In addition to his role at the Robotics Institute, Mertz is the co-founder of RoadBotics, where he uses deep learning analysis of smartphone images to identify developing potholes and other road infrastructure issues in real time. More than 100 governments around the world now use RoadBotics' pavement assessment system.

In consideration of the work he had done with RoadBotics, Mertz wondered if he couldn't use the same deep learning approach to detect signs of impending landslides, like fast developing cracks in the road, deformed guard rails, debris on the road, deformation of hillsides or tilting trees.

Anatomy of a Landslide

Mertz learned early on that the switch from potholes to landslides wasn't simply a matter of horizontal versus vertical.

Landslides have a wide variety of causes and, by extension, a wide variety of contributing factors. A hill comprised of red clay collapses differently than one made of shale. The leaning of the surrounding foliage could be as valid an indicator as the progression of the hillside itself, as could the bulging of nearby retaining walls. And not all cracks and deformations are equal: the location of a crack in the soil can radically alter the implications of a later geological event.

Additionally, there were factors that pictures of the hillside itself could not effectively capture. A crack in the road infrastructure could be the indicator of an oncoming landslide, as well as a clogged storm drain rerouting water to a nearby hill.

In order to find patterns and predict outcomes, deep learning algorithms require large amounts of existing data. Without seeing thousands of pictures of intersections, deep learning wouldn't be able to help an autonomous vehicle differentiate a stop sign from a yield sign. Without linguistic data, it couldn't help Google Translate instantaneously determine that a passage is in Spanish and not Italian. By extension, in order to understand the trends and patterns behind the region's landslides, deep learning needs a significant amount of historical and geological data.

Thus, in order to train his model and get a more holistic picture of the anatomy of a landslide, Mertz needed to go outside of his discipline.

"It's a really complicated matter," Mertz said. "You need the kind of cross-discipline collaboration that's here at Carnegie Mellon

University—not just experts in computer science and machine learning but experts in geology, in infrastructure, in water and sewage—to come together and tackle the issue."

In a partnership with Allegheny County, Mertz is analyzing five sites of potential landslides to evaluate the viability of his system.

Ultimately, Mertz's project is not only about being able to predict and prevent landslides. He also intends to use this work to more equitably direct the infrastructural change necessary to support this kind of prediction and prevention.

"I'm not sure that landslide prevention was in the vernacular even three years ago," Lightman said. "But now, I'm hearing it more often in conversations about future investments in the infrastructure."

In its most recent Infrastructure Report Card, the American Society of Civil Engineers gave the American infrastructure an overall D+ grade. In particular, several of the elements of the infrastructure that were central to landslide formation, such as roadways, levees and wastewater, also received D-range grades.

However, the resources needed to address these gaps in the infrastructure are sometimes unequally distributed among neighborhoods and many infrastructural decisions often deprioritize the needs of areas with marginalized populations.

"Based on our model, there are many indicators for landslides that could help inform policy and budget allocation," Mertz said. "Sometimes, these decisions are affected by bias. But by providing an objective representation of the infrastructural decay, we're hoping to support a fairer means for allocating these resources."

Provided by Carnegie Mellon University