Geographers use big data to predict how slope affects human travel rates

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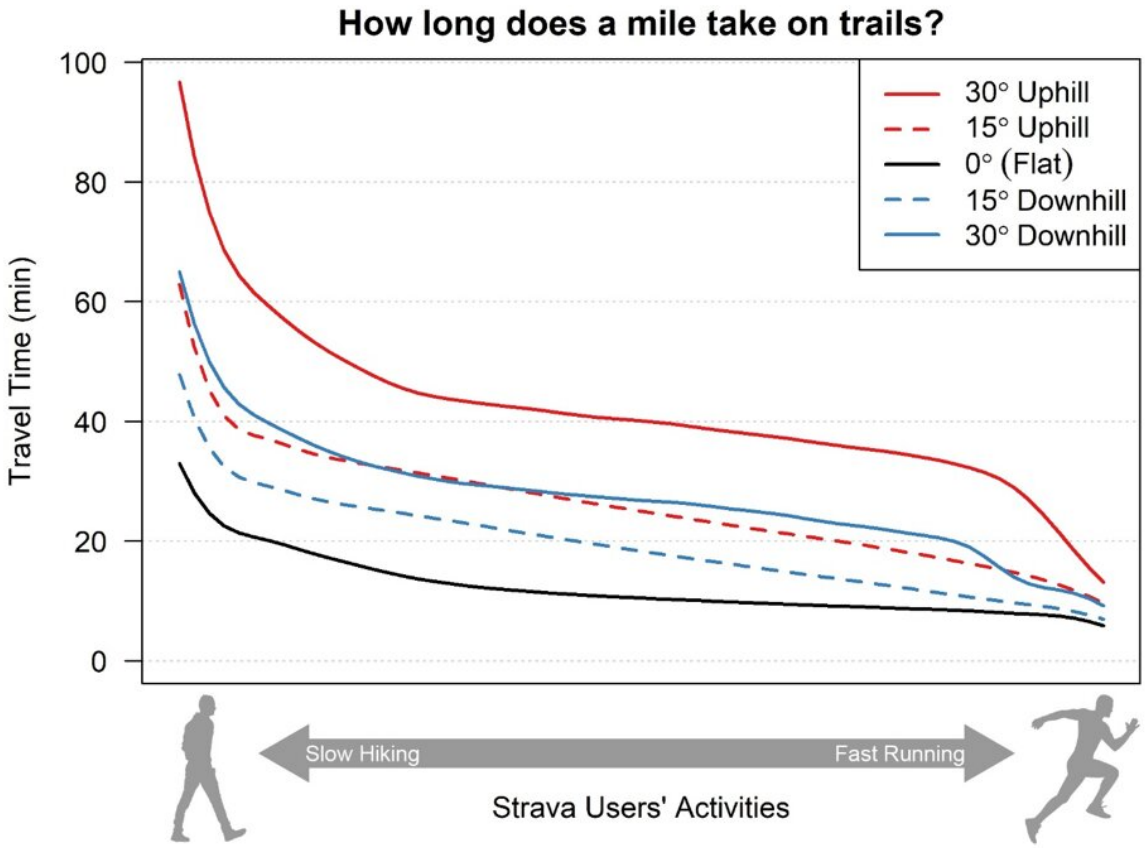

The amount of time it takes to traverse a mile of trail, depending on the slope of the trail, the direction of movement and the level of energy expenditure. Credit: Michael Campbell

Have you ever been running on a sidewalk making pretty good time, then hit a hill and slowed way down? If so, you've experienced how slope affects travel rates. For most of us, understanding how slope steepness impacts our speed is a matter of fitness. For others, such as wildland firefighters retreating from the fire line to a safety zone, predicting how long it takes to move across terrain can be a matter of life and death.

Fire crews, city planners and search and rescue teams are just some of the many groups that can use mathematical models to predict how slope affects travel rates. Existing models have two big problems. They're based on datasets with very small sample sizes and they ignore how differently people move through their environment—walking and running up the same slope will yield very different travel rates.

A team of geographers developed a series of models that strongly predict how terrain slope affects human travel rates. Using a massive, crowdsourced fitness-tracking database, the geographers analyzed GPS data from nearly 30,000 people around Salt Lake City, Utah. The individuals hiked, jogged, and ran a combined 81,000 miles, equivalent to more than three trips around the Earth's equator. The resulting models are the first to account for variability in travel rates between slow, medium and fast movers.

"This will revolutionize our understanding with how terrain affects pedestrian movement," said Michael Campbell, assistant professor at Fort Lewis College and lead author of the study. "From a firefighter perspective, under normal conditions a fire crew may have ample time to hike to a safety zone, but if the sh*t hits the fan, they're going to have to sprint to get there. We tried to introduce predictive flexibility that can mimic the range of conditions that one might need to consider when estimating travel rates and times."

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Geography.

Big data

The researchers leveraged crowdsourced data from Strava, a social fitness application that tracks cyclists, runners, hikers, and swimmers using GPS data via users' mobile phones and other GPS-enabled devices. Strava Metro is a program that distributes large quantities of aggregated, anonymous GPS data to entities such as local and regional governments to aid in transportation planning. To date, Strava Metro's collaborations have primarily revolved around cycling and running data in urban environments. The geographers are some of the first to use its hiking, running and jogging data from activities on trails, and are the first to use big data to estimate the relationship between slope and travel rates on hiking trails. The geographers assessed slope with lidar, which uses laser pulses to measure topography within a few centimeters. Previous studies relied on much coarser estimates to determine how slope impacts travel rates.

"Calculating how quickly people move through the environment is a problem more than a century old. Having data from such a large number of people moving at all different speeds allowed us to create much more advanced models than what's been done before," said Philip Dennison, a professor in the Department of Geography at the University of Utah and an author on the study. "Any application that estimates how fast people walk, jog, or run from point A to point B can benefit from this work."

Steph Hannon, the chief product officer of Strava, added, "This is a fascinating application of Strava Metro's data set outside of urban mobility and infrastructure planning, and we're thrilled about the life-saving implications of this study. I'm glad our data insights can support work that protects firefighters while they work hard to protect the rest of us."

The most widely used model to estimate travel rates by slope is Tobler's hiking function. In 1993, geographer Waldo Tobler fit a mathematical function to a figure that summarized empirical data collected in the 1950s, prior to the age of GPS. People have used Tobler's hiking function to estimate evacuation times for tsunamis, missing person search and rescue and wildland firefighter escape routes. The next most widely used function, called Naismith's Rule, has been around since 1892. A Scottish mountaineer went on a hike, then wrote an entry in the Scottish Journal of Mountaineering. Based on his personal experience, he wrote that one should budget three hours for every three horizontal miles traveled, and add one hour for every 2,000 vertical feet ascended.

"Hundreds of people are using these slope travel rate functions based on a random Scottish dude from the 1890s and some data from the 1950s," said Campbell. "We wanted to do better."

In 2017, Campbell, Dennison and others experimentally measured slope and travel rates for 37 people, which was the largest experimental dataset until Irmischer and Clarke recorded travel rates with 200 people in 2018. The new study used data recorded between July 1, 2016, and June 30, 2017 from nearly 30,000 individuals, totaling nearly 1.1 million data points. The massive amount of data allowed the geographers to develop flexible functions on a spectrum of travel speeds, from the slowest hikers in the 1st percentile to the fastest runners in the 99th percentile.

According to the results of the study, a slow walk on a flat, 1-mile (1.6 km) trail takes about 33 minutes on average, whereas that same level of exertion on a steep, 30 degree slope will take about 97 minutes. On the other end of the spectrum, a fast run on a flat, 1-mile trail takes about six minutes, as compared to 13 minutes up a 30 degree slope. People move most rapidly on a slightly downhill slope, and travel rates were faster for downhill than uphill movement. For example, walking down a steep slope of 30 degrees was done at the same speed as walking up a slope of

16 degrees.

Tuning big data to firefighters

The data have some limitations. Because it's crowdsourced, the data are messy. And due to its anonymity, the researchers don't know about the individual runners. If they had information about each person's fitness level, they could develop more nuanced functions to predict travel times.

Staring this month, the geographers will apply their new models to wildland firefighters. During their spring training, nearly a dozen fire crews in Utah, Idaho, Colorado and California will use GPS trackers to record their movements and log their travel rates. This will allow them to better understand the travel rates of the unique firefighter population, who are often traversing rugged terrain, working long hours, and carrying heavy packs.

"We need to find where firefighters fit along this spectrum from the big data," said Campbell. "Telling firefighters that we can predict how long it will take to get to safety zones using data from a diverse population of Strava users is not going to be as convincing as data that the fire crews themselves provide. Anything we can do that improves travel rate estimates for firefighters will provide an added safety margin and will hopefully save lives."

Provided by University of Utah

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