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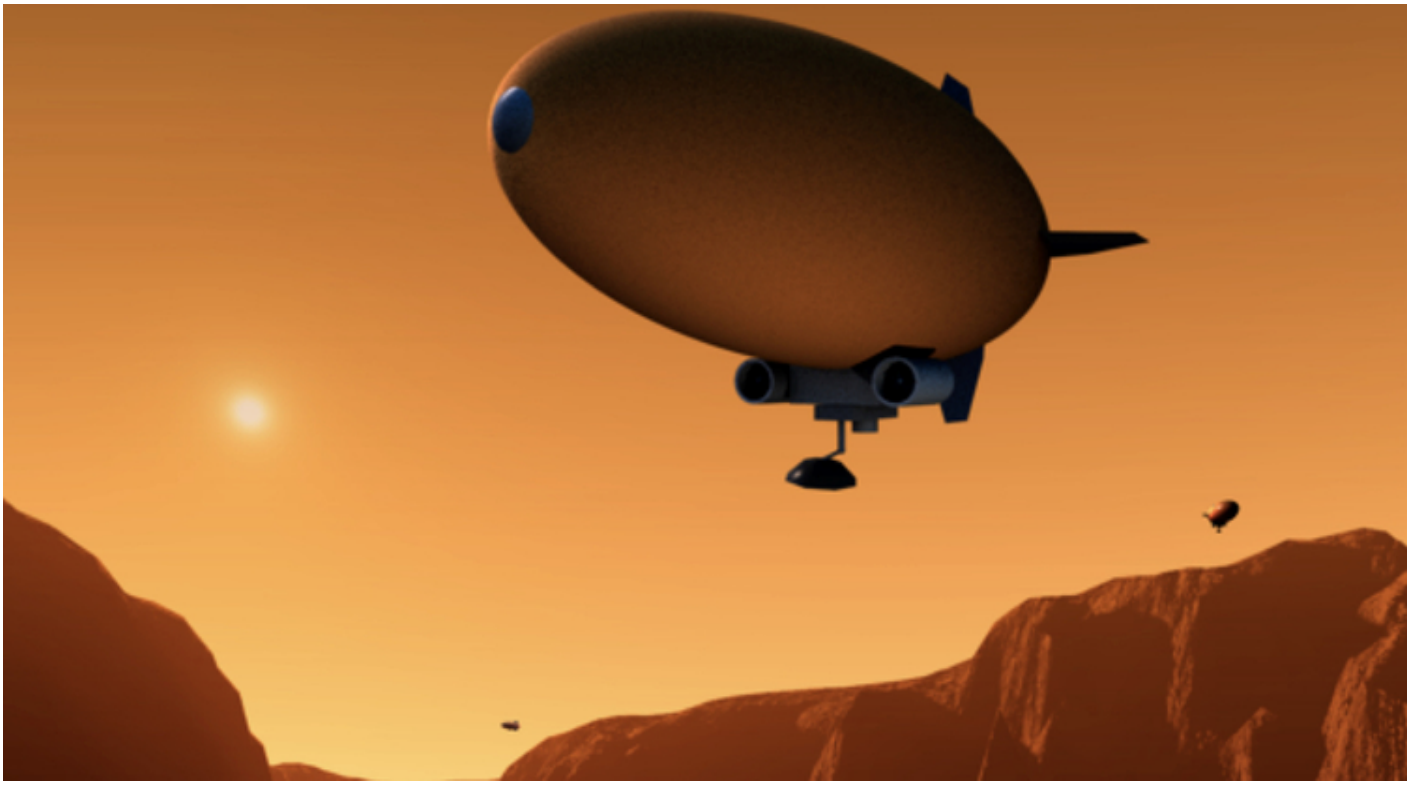


Blimps could one day play an important role in selecting interesting objects for closer examination by rovers on the ground or on the surface of lakes on alien planets. (Image: Wolfgang Fink)

Building Curiosity Into Technology

UA engineers are working on endowing a robot with the ability to spot the unusual, so that it can explore other planets or environments on its

own instead of merely executing pre-programmed commands.

By Daniel Stolte,University Relations - Communications | Aug. 27, 2015

EXTRA INFO

You can watch a video about the lake explorer prototype **here (https://www.youtube.com/watch?v=zF7o7yuSdVM)** [1].

The year is 2045.

Geologists have landed on various bodies in the solar system and are exploring alien landscapes. On Mars, a geologist climbs up a slope after spotting a peculiar-looking rock. On Saturn's moon Titan, a blimp glides through the brown haze, surveying the methane lakes below while directing another explorer to cross the lake and investigate an odd feature sticking out above the surface.

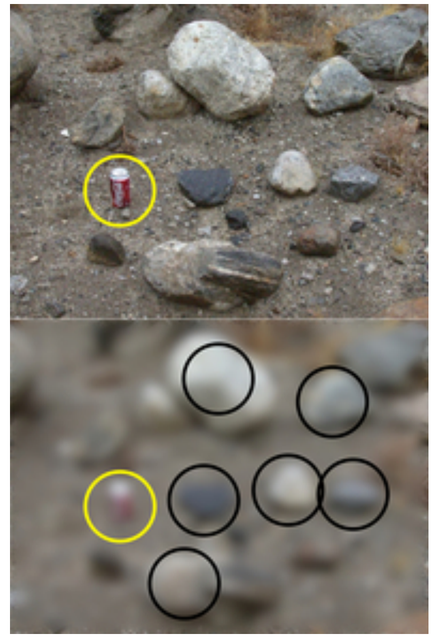
Endowing machines with a sense of "curiosity" begins with a clever mathematical algorithm that assigns objects such as rocks (top) to different categories based on their features (bottom). (Images: Wolfgang Fink)

These planetary geologists are not human. They're robots, built in various shapes and forms. Some are rovers, others hover in the atmosphere and others float. All have one thing in common: They are hardwired to explore the unknown. They are curious.

Unlike conventional planetary rovers, which are basically cameras on wheels controlled by humans on Earth, these new planetary explorers go about their work autonomously, capable of making decisions on their own.

"In environments where you need a curious explorer with the ability to spot unusual and interesting objects, but you either can't or don't want to send humans, you have to rely on robots with a built-in sense of curiosity and the ability to make decisions autonomously," said **Wolfgang Fink (http://ece.arizona.edu/wolfgang-fink) [2]**, who heads the **Visual and Autonomous Exploration Systems Research Laboratory (http://autonomy.arizona.edu/) [3]** at the University of Arizona's College of Engineering.

"To accomplish this, we have to instill algorithms in the robot that will create 'excitement' about an object if it is different from the surrounding environment."



Currently, Fink and his team are working on getting their rovers to spot an object of interest, such as a Coke can (top), among a field of uniform-looking rocks (bottom). (Image: Wolfgang Fink)

In other words, the robot has to be able to identify scientifically promising objects without being told where to go and what to look at by its human controllers back home on Earth — just as a human geologist wouldn't turn over every single rock but would focus on those that stick out from their surroundings.

Spotting promising features in an alien environment would be a tall order to ask of a well-trained, highly skilled scientist. To ask the same of a machine is daunting.

In his lab, Fink and his students experiment with prototypes of land and sea rovers, coffee-table-size boxes mounted on caterpillar tracks and on a catamaran-like watercraft, respectively. The rovers are a long way from being able to survey Mars rocks on their own, but the engineers have equipped them with basic decision-making power. Relying on LIDAR sensors, the rovers use lasers to scan their surroundings for obstacles. They can home in on objects that are placed or maneuver around them.

With on-board cameras and a laser range finder, this prototype of an autonomous rover is capable of avoiding obstacles and homing in on target

To get to the level of curiosity that a human geologist would have, much more than that would have to happen, said Fink, an associate professor and the inaugural Edward & Maria Keonjian Endowed Chair in the **Departments of Electrical & Computer Engineering (http://www.ece.arizona.edu/) [4]**, **Biomedical Engineering (http://bme.arizona.edu/index.html) [5]**, **Systems & Industrial Engineering (http://www.sie.arizona.edu/) [6]**, **Aerospace & Mechanical Engineering (http://ame.arizona.edu/) [7]** and **Ophthalmology & Vision Science (http://www.eyes.arizona.edu/) [8]** in the UA College of Medicine.

structures.

"The rover must be able to find strange things on its own," Fink said. "Imagine you are in a rock field on Mars, and every rock looks exactly the same. That's not very exciting. But let's say you suddenly spot a Coke can — that would be very exciting. Humans are drawn to anything that sticks out from the ordinary like a sore thumb. That's where curiosity comes into play."

Such an explorer must be automated and yet autonomous, Fink explained.

"When human controllers told the Phoenix Mars Lander to deploy its sampling arm, that's automation," he said. "But when a robot develops the intent to extend its arm, that's autonomy. For that to happen, you need to implement robotic curiosity."

Such a "curiosity algorithm" is what Fink is after. It requires a combination of algorithms that help the robot function autonomously and enable it to make decisions based on environmental anomalies and obstacles.

"Such a future Mars rover would come uploaded with pre-existing knowledge, but you need an aspect of the system that can deal with the unexpected," he said.

With funding from NASA, Fink's group has developed a concept called tier-scalable reconnaissance, which has received three patents and a NASA Board award. It consists of an orbiter that maps and surveys a planetary surface from high up and a flock of rovers on the ground. In sufficiently dense atmospheres, the system could include one or more blimps communicating with the orbiter and controlling the rovers on the ground.

"If you have an orbiter that just goes around the planet without the ability to look for anything out of the ordinary, it collects terabytes and terabytes of data, but it is not likely to document change, even though that is what you are after," Fink said. "An orbiter with curiosity, however, will only send back data it thinks are interesting."

Fink has designed a mathematical algorithm to help a team of robotic explorers prioritize their targets.

"In a field site of, say, a hundred rocks, you don't want to send your rover to investigate 99 of them before it finds the one that potentially can be a game changer," he said. "We can mathematically determine which of the rocks has the potential to significantly change our knowledge about that environment."

To do this, the surveying unit (e.g., the blimp) takes a survey of the study site and analyzes each rock for certain parameters, such as color, brightness, shape, angularity (jaggedness vs. smoothness) and spectral composition. The algorithm then takes these multidimensional data and divides the objects into clusters based on their similarity. Next, the algorithm switches the objects between all clusters and notes how the overall clustering quality changes as a result.

By doing this for each object, a listing emerges that ranks each object based on how much it sticks out. Applied to the hypothetical Coke can, this procedure would list the can as the number one "oddball" object among an assortment of Martian rocks.

"It narrows things down so that the rover can then investigate only the most interesting object, even though it was less conspicuous in the beginning," Fink said. "This would be a help for the human controllers of the mission who have to prioritize targets for study, especially when you can perform only a limited number of experiments."

Such tiered exploration algorithms could help with mission planning even in existing scenarios. For example, the wheel damage suffered by the Mars rover Curiosity from unexpectedly pointed rocks too small to show up on survey images taken by an orbiter might be preventable if future missions integrate terrain classification algorithms with observations made by the rover once it's on the ground — and use the newly found information to chart alternative traverse routes. Fink has developed such an algorithm and presented it at two conferences earlier this year.

Until then, several challenges have to be overcome. Fink and his team are working on integrating the object classification and prioritization algorithms into the rovers' "sensory system."

"It's one thing to feed the algorithms with data about the environment by entering them into a computer, but it's another if that input actually comes from the rover," Fink said. "For example, when you look at a black surface in bright sunlight from a bad angle, your camera algorithm might see it glaringly bright. 'Black' in a lab environment is not 'black' in an outside environment."

For now, the rovers are still learning to "understand" a Coke can placed on the floor. It probably will be awhile before they could spot one on Mars.

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