

Diagnostics for Drilling Fault Prediction in Planetary Drills

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Searching for evidence of ancient climates and extant life in icy planetary environments will require robust hardware and software to obtain surface and subsurface samples. Ice drills like The Regolith and Ice Drill for Exploring New Terrain (TRIDENT), a 1 meter rotary percussive drill manufactured by Honeybee Robotics, are uniquely suited hardware for obtaining cores and samples, but functionality beyond earth's immediate orbit will require autonomous software operation. Robotic ice drills on Mars or other planetary bodies must respond to potential indicators of fault and prevent hardware failure to allow clean acquisition of subsurface samples. Past arctic planetary-analog fieldwork in Houghton Crater (Glass 2025) has given us methods for identifying and preventing drilling faults in arctic environments with periglacial features, like ice lenses or permafrost. This will better inform development of autonomous drilling and sampling methods in planetary environments.

Faults can be categorized into five categories: Binding faults that increased torque to friction along drill string, choking faults, where pulverised cuttings caught in the borehole causing increased torque, hard-materials faults, where rate of penetration is stalled despite increased percussion and torque applied to the drill string, corkscrewing faults, where flutes become caught on protruding rock, and bit inclusions, where small gravel is caught in drill flutes causing torque increase. These are often diagnosed later when reviewing time-series telemetry data.

Changes in force telemetry data indicating faulty conditions have a high likelihood of online prediction with tailored methodologies (Boelter 2025). Using change point detection techniques, we can monitor change scores in telemetry data, which often spike prior to faulty conditions for torque or weight on bit. We can also monitor downward velocity, to monitor stalled or slowed drilling progress approaching a velocity of zero. We can also monitor percussive sound wave data during active percussion, as higher frequency or skipped percussive beats are fault indicators. Active percussion indicates hard or differing subsurface composition. We use methods that calculate a novelty curve corresponding to an increase in spectral energy of the vibration signal. Then, an algorithm is used to pick which points in the novelty curve correspond to beats. Beat bounds are found from the local minima of the novelty curve. After applying the Fourier transform to beats, features like frequency peaks and overall energy are used to determine if the beat denotes a fault or nominal operation. Analysis of test data shows that non-faulting beats typically have a frequency peak around 6 kHz and faulting beats tend to have higher frequency peaks and more overall energy.

Preliminary results during May 2025 lab testing indicate change point detection methods are accurately able to catch subtle telemetry signal changes preceding faulty drill conditions and collected sound wave data also indicates faults can be predicted through sound wave amplitude changes and faulty and skipped beat detection. These methods will be verified during analog arctic field testing in July 2025 at Houghton Crater.

References

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