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Drill Automation for the Space Environment: Lessons Learned

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Abstract

This paper examines drilling autonomy in the context of space exploration and how it might differ from autonomy required in an oil well drilling.

The main driver in the planetary drill automation is a large communication delay (i.e. the drill can not be remotely controlled) whereas in the petroleum well drilling it is reduction in manpower as well as it serves to remove human operators from a dangerous location where heavy equipment is operated 24 hours a day regardless of the weather conditions. Both planetary and petroleum drills share common problems such as data ambiguity (the same data can come from two different events) as well as a large number of data inputs that need to be processed and analyzed in real time for automation to be effective.

The petroleum industry is profit driven; thus reliability of various mechanical components is carefully optimized since higher reliability means also higher cost. In the space industry, the reliability of all systems and especially those that form a single point failure must be very high. This requires a lot of testing and makes space exploration very expensive.

Since automation is inherently expensive, a careful analysis needs to be performed in order to determine which operations may be optimized and which should not. This is because some operations are still done better and cheaper with humans.

Introduction

Automated control systems in the petroleum well drilling range from planning tools, to help in the selection of drill bits and their operating parameters; to specific control algorithms that are aimed at detecting and controlling particular phenomena, such as kicks and influxes or stuck pipe. Little work has been done to develop real-time control procedures to control the drilling operating parameters such as weight on bit and rotary speed. This may be because of the complex nature of the decisions that go into this process, or the fact that experienced drillers are very skilled in making such decisions based on their own knowledge and abilities. Since such skilled drillers are readily available, there is relatively little incentive to replace them by automated systems.

Unfortunately, skilled drillers will not be available in person on the drilling rigs used for planetary drilling, but it is their abilities that will need to be mimicked in the automatic control systems for these missions. It is therefore likely that the required control systems will have to be developed from scratch.

One of the peculiarities of drilling, that it possesses in common with all the Earth sciences, is the characteristic of “geologic uncertainty”. The geologic uncertainty is present because every drilling location is different. This makes it difficult to predict what conditions will be encountered in any particular borehole. Equipment must therefore be capable of handling a wide variety of conditions, while the techniques used to control operations must envisage and deal with a broad range of circumstances. A related consequence of geologic uncertainty is that, since every hole is different, it is difficult to demonstrate in any particular circumstances that a new piece of equipment has performed better than the standard, or that a control process has actually improved the drilling performance. Added to this difficulty is the fact that drilling operations are expensive and in petroleum well drilling, dangerous. Note that for this reason, in oil well drilling the risks associated with introducing new technology are high while the benefits may not be clearly visible. This combination of disincentives has undoubtedly had a cooling effect on the introduction of new technology in general and on automation in particular.

Planetary Drilling

In order to determine the required level of autonomy in planetary drilling, it is important to understand the constraints imposed by the extraterrestrial environment [for a detailed review of these constraints, please refer to Zacny and Cooper, 2006]. These constrains include limited power/energy, limited mass, large temperature fluctuations, temperature extremes, low pressure or vacuum conditions, and communication delay that can range from two seconds (one way) in the case of the Moon to 20 minutes (one way) in the case of Mars.

Electrical Power. Mars Exploration Rovers (MER) power budget initially was in the range of 800 Whr per day. This limit was set by the size of the solar panels and the season on Mars at the time when the rovers reached the planet (i.e. angle of sun with relation to the surface of the solar panels). As dust