WHITE PAPER

PREDICTIVE MACHINE LEARNING FOR REAL-TIME DRILLING OPTIMIZATION -

a journey from an exotic tool to a standard operating procedure

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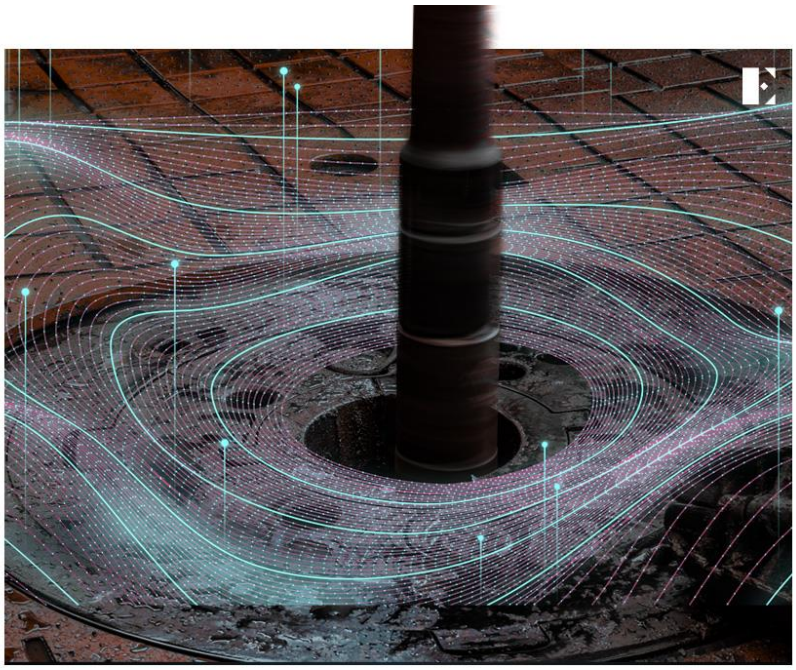


After years of academic and private R&D, numerous product development attempts, hundreds of millions of $ spent, grand scale JV's created, etc... - Machine Learning (ML) for drilling optimization still remains in the category of "interesting things to try".

It is applied occasionally and locally, it works on some wells and doesn't work on others. Some successes are published as big achievements, but achievements of several years' worth of R&D and testing, and not achievements of developing a technology that can be easily applied to your next well, and scaled across your entire operation.

Why?

By the means of this article I would like to open a discussion regarding a possible pathway of Machine Learning to be integrated into standard operation procedures for planning and for real-time operations.

A good place to start is to get a relevant reference, something that was wild some time ago but now you can't even think of drilling a well without it. EDR and WITSML streams and real-time monitoring. These started to be developed in the early 2000's, followed by early adopters (BP and Statoil) 2003-2005, mass deployment in 2009-2011, and becoming industry standard in 2012 going forward. Approximately 10 years on, we have a technology that brings tremendous value to gather data, monitor real-time operations and make decisions as you drill while being miles away from the drill rig.

For ML we are currently at “early adopters” stage with lots of trial and error. Can we move faster to the next stage ? To answer this big question, let’s answer a few other questions first:

1) **Is the industry ready for ML technology to be applicable and to bring immediate value?**

Most definitely yes!

- Operators/contractors have accumulated tons of time/depth drilling data and digital well reports, 90% of which is not being utilized for any data analysis. Lessons learned are not incorporated on a regular basis. The same types of drilling incidents, NPTs and ILTs continue to occur, even though the pattern of events or operational mistakes could have been quite easily derived from the previous wells, and predicted for the new ones.
- Data quality is now becoming much better and more standardized. Same formats, same scales, etc… Data pre-processing, clean up and preparation is still very much required, however it’s becoming possible to automate this process.
- Internet connectivity and rig-office real-time communications have been significantly improved, allowing ML to be easily added on top of existing data streaming, monitoring and visualization.
- Sparse but successful applications of ML on some case studies (as part of general digital transformation initiatives) have demonstrated value and triggered a strong interest in the industry, opening the path for full scale development and deployment of ML/AI applications.

2) **Are operators/drilling/service companies ready to adopt ML and integrate it into their SOP ?**

Most definitely yes!

- **About the value**. It has been clearly recognized by operators/contractors that data analysis and ML technologies in particular can bring significant value, no matter onshore or offshore, conventional or unconventional. Some companies have been actively hiring data scientists (which is a good thing) and even trying to develop internal data analysis software solutions (unsuccessfully in most cases, just like any in-house software development usually is).
- **About the human factor**. With a strong growth of drilling activity around the world, companies are facing challenges in hiring experienced and well

trained rig personnel, resulting in human factor becoming a primary reason for NPT and ILT. Automated Machine Learning solutions can significantly reduce the errors due to human factor, and improve reliability and consistency across all of the wells drilled.

- **About the infrastructure.** Some companies already have excellent data management infrastructure in place, consisting of real-time operations centers (RTOC) and established decision making and communication processes between RTOC and the rig. Other companies, that don't have an RTOC, work closely with the drilling contractors to improve drilling performance. In any case, whether ML is deployed on the operator or contractor side or both, it ultimately brings value to both.
- **About the SOPs**. Adopting ML doesn't require a significant change in the existing Standard Operating Procedures and can be quite easily integrated into the current practices. That process will involve adding workflows on communication and decision making for the situations when the alarms, warnings or recommendations are triggered. The procedures will need to be put it in place to rapidly validate alarms and take actions to mitigate the risks or optimize the performance.

3) **Is there a technology on the market that can be scaled to "mass production" and if not, what needs to be done to get there?**

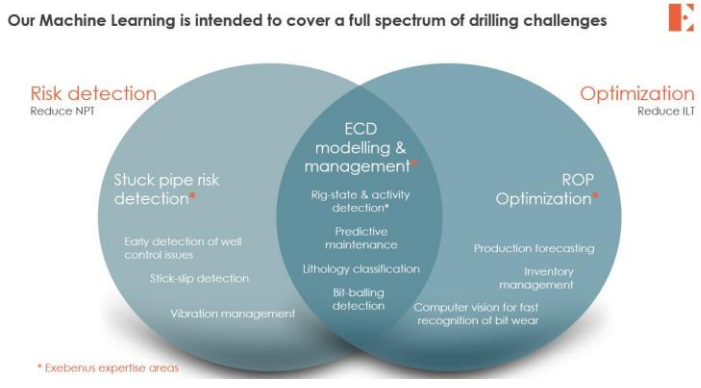
As much as I want to say Yes, it's Exebenus!...the answer is no.

- **About Automation**. Mass usage means full automation (not to confuse with drilling automation!) on absolutely every stage of ML implementation: 1) pre-training of predictive models, 2) data preparation and clean-up, 3) real-time operations, 4) ML output (warnings, alerts, recommendations) validation and 5) re-iteration to improve the models. The goal is to have minimum or close to zero human intervention needed when dealing with ML. No doubt we will still need to have drilling engineers to make decisions and implement actions, however the system itself has to be a true plug & play solution with no compromises. It has to be seamless, easy to read, easy to follow, agnostic to vendors or equipment and overall completely hassle-free. Most of the drilling ML solutions currently on the market (not including Exebenus) require weeks of man hours (before the job) to pre-train the models on the offset wells, configure the algorithms, provide planned BHA

types, well trajectories, expected lithologies, etc… This approach cannot possibly lead to having a scalable solution. You need your drilling intelligence systems to be generalized, universal, self-adaptive and ready-to-go in order to give you consistently reliable results for any type of well anywhere you drill.
When you start your car, you don't think of all the safety features it has, but you know that they are running in the background and are there to help you if needed. Imagine if you had to spend hours to prepare ABS system on your car every time before you drive. I doubt we would be still be using it.

- **About trust.** Users need to develop trust in ML doing the right thing. That means, the system has to have a close to zero rate of false positive alarms, which is a challenge for probably all current ML products on the market. We (at Exebenus) have devoted significant R&D time on this issue, resulting in proprietary technology that delivers a 94% precision metric. Going back to car analogy, when you receive a warning from your ABS about a slippery road you don't spend time trying to figure out if it is a true or false positive. You simply trust that it is a valid warning and you take appropriate actions. Another important factor of trust is knowing that the ML system is giving you not only valid but also safe recommendations. For example, if you are getting recommendations on RPM or WOB to increase your ROP, you want to make sure that at the same time you are not increasing risks of getting stuck pipe, vibrations or an accelerated bit wear out.

- **About the expertise**. ML Solutions need to be initially scoped by drilling engineers, for drilling engineers, and only then designed and built by data scientists and software engineers, in that order. Attempts of bringing some generic and industry-agnostic ML (also sometime over-optimistically called AI) solutions, created by IT or consulting companies, into the drilling operations (and probably any other parts of O&G industry) have all to my knowledge miserably failed.
- **About the approach**. One last but critical ingredient is methodology, approach to selecting algorithms for specific drilling issues, choice of fitted models and other very cool data science stuff, but you need to become an Exebenus client for me to share this one with you -))



4) **Are tech companies on the market, offering ML technologies, ready to support such a mass scale deployment ?**

   No, they are not.

   - **About the support**. The end game is to have a technology that is automated (again, not to confuse with drilling automation) to such extent that is doesn't require a constant (or any) drilling engineering domain expert support to set up the system or validate the results. Only to make final decisions and implement appropriate actions at the rig. No existing tech companies to my knowledge have such a product yet. Support is currently needed on all levels: configuring the applications, preparing the data, understanding, interpreting and validating real-time warnings and recommendations, looping back for improved performance, etc. Which means lots of time/cost on both operator and contractor sides.
     However, some companies (guess which one in particular -)) are getting close to have a 100% "no-human needed" solution that would take only a few minutes to go from installation to a full-scale operation.
     Coming back to my favorite car analogy. Have you ever called an engineer who designed an ABS system on your car to get to know how to make it work?

Summary

There is no doubt that real-time Machine Learning for drilling management, optimization and hazard prevention will become as standard as any other common technologies we routinely use at the rig now. **Because if it works, then why would you ever drill without it?**

Do we need another 6-8 years for Machine Learning to become a standard technology, applied by default on every rig operation in the world? Most definitely not! My forecast: 2-3 winning technologies (and count on Exebenus to be one of them-)) will be initially deployed to around 70-85% drilling rigs worldwide in the period of next 2-4 years: 1 year to mature the product to full automation, another year to gain trust and 1-2 more years for deployment. The industry is ready and the pathway is open, now it is only a matter of time, talent and joint effort to make it happen.