Annual Report 2022

DigiWells

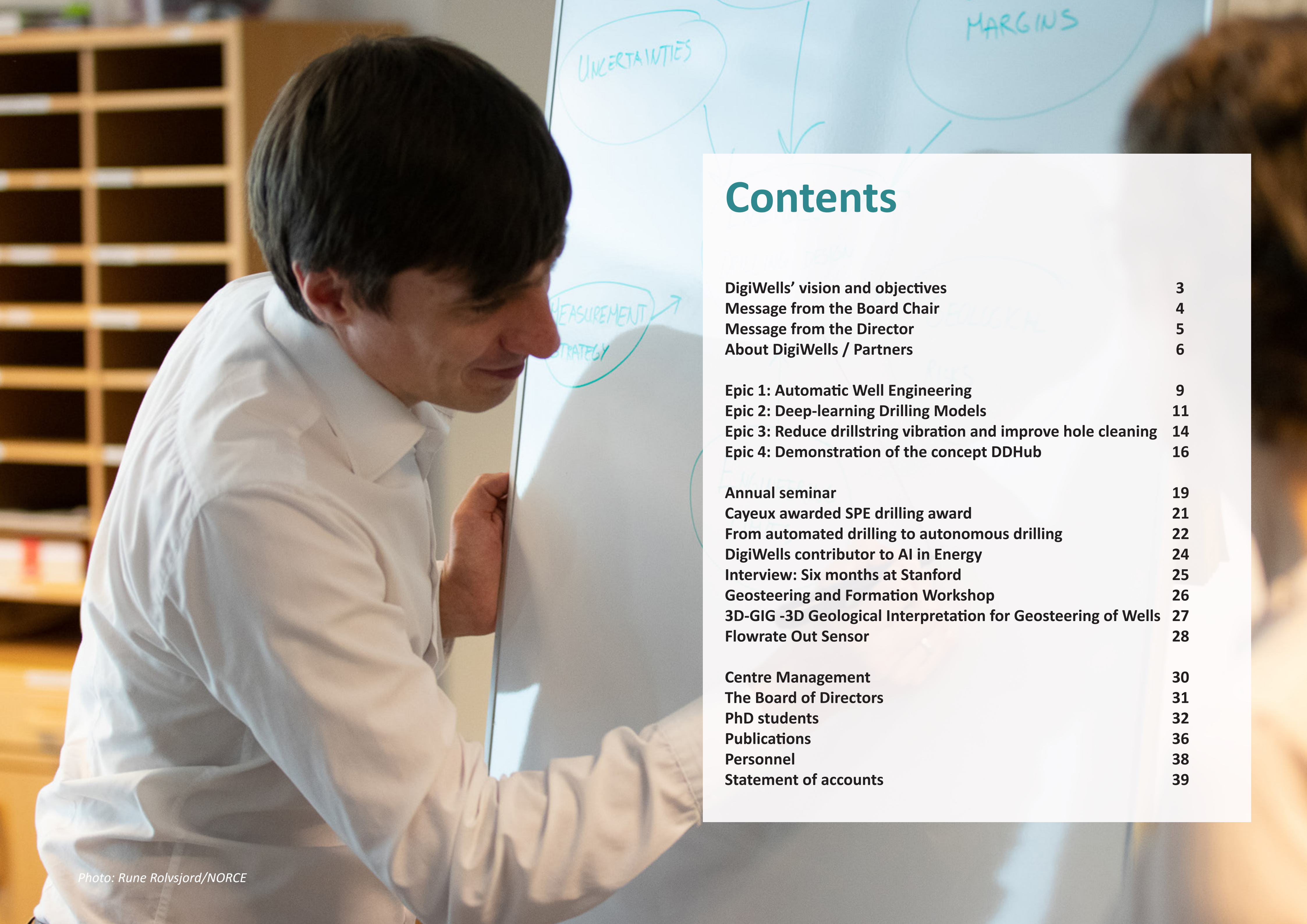

Photo: Rune Rolvsjord/NORCE

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DigiWells:

Digital Well Center for Value Creation, Competitiveness and Minimum Environmental Footprint

VISION
Unlock petroleum resources through better drilling and well technology.

MAIN OBJECTIVE
DigiWells aims to develop new knowledge, methodologies and innovative solutions to optimize the well delivery process with special attention to challenges and possibilities at the Norwegian Continental shelf.

Subobjectives:

- Develop more efficient work process for planning the well delivery process by systematic workflows that addresses the uncertainties in a systematic way
- Develop techniques for fast modelling of the drilling and formation evaluation processes to enable optimization and improved decisions
- Investigate and develop solutions for automation and autonomous well delivery process
- Investigate and develop new measurement techniques that will improve process control
- Investigate and develop innovative hardware concepts to improved drilling performance based on in-depth understanding of the drilling process
- Support standardization and interoperability
- Strengthen collaboration between academic and industrial players
- Ensure industrial relevance and generate new ideas by performing casestudies in collaboration with end users

From left to right, Helga Gjeraldstveit, Tron Golder Kristiansen, Anar Ismayilov, Aina M. Berg, Halvor Kjørholt, Tron Helgesen and Erlend H. Vefring (Photo: Rune Rolvsjord, NORCE)

- Digitalization is not optional

Dear reader,
A new year, and in front of you a new Annual report from Digiwells with a lot of information of the last year's activities. The overall DigiWells focus is developing and applying digital technologies to improve well construction with the aim of increasing efficiency, reducing costs, and minimizing environmental impact. DigiWells is also a valuable supplier of competence through several PhDs and Postdoctoral researchers.

From an operator's perspective digitalization is not optional, it is rather a requirement. Data acquisition and digitalization are becoming more and more integrated in everything we do. We must adopt to that and become more data driven and utilise digital technologies to make planning and operations more automated, consistent and with less errors.

DigiWells works with a portfolio of solutions to meet these ambitions in a collaboration between academia and the industry, generously supported by the Research Council of Norway.

In DigiWells we see the power of combining research and digital technology. A number of Apps have been developed to simplify implementation. The nature of developing digital technology is so that even if the ultimate goal is long term, the development can deliver valuable products along the road.

DigiWells' research encompasses a wide range of technologies, including artificial intelligence, machine learning, data analytics, and sensor technology. The research is performed in closely with industry partners to develop and test new digital solutions for well operations, and has a particular focus on developing technologies that can be widely deployed in our operations.

Looking forward to exciting research also in the coming years!

Halvor Kjørholt
Board Chair

Halvor Kjørholt (photo: Rune Rolvsjord/NORCE)

- Creating value through synergies

The center has been running for a little more than two years, and many results have been achieved during this period.

For 2022, four main activities have been prioritized. The main activities have been automatic well engineering, deep learning, interoperability, and distributed drilling control. These activities were prioritized in dialogue with especially the end users and are to a considerable extent continuations of activities started initially in the center. We have been highly active in dissemination of the research, both nationally and internationally. Now six PhD students are involved in the center.

Eric Cayeux, who is heavily involved in the center received the international SPE Drilling Engineering Award from Society of Petroleum Engineers for 2022. The prize is given to people who have made significant technical and professional contributions to the industry. This is very inspiring for the whole center.

An important activity continues to be involvement of key personnel from the center in international forums and committees to support interoperability and standardization. Results from the center were donated as open source and are expected to significantly impact the industry.

The two-day annual DigiWells seminar was arranged with one day for only the center partners and one day which also included representatives from key players outside the center including service companies, industry clusters and public authorities. This was important for dissemination and to strengthen relations. An international two-day workshop on geosteering in Stavanger was also arranged with 90 participants.

An important goal in connection to the center is to establish spin off projects. A spin-off project entitled "3D geological interpretation for geosteering of wells" will start in 2023. During 2022, an application to the Research Council of Norway's Verification program related to flowrate out measurement was submitted. This has now been given support and will start in 2023 to progress towards industrialization and commercialization.

The center's focus is on developing more efficient and environmentally friendly technologies for well construction of petroleum wells, geothermal wells, and wells for CO_2 storage. However, we see that the work performed in the center also gives important contributions to automation, autonomy, and artificial intelligence in general.

We are looking forward to an exciting 2023 with further progress on research, development, innovation, collaboration and support to industrialization of results.

Erlend H. Vefring, Centre Director, NORCE

Erlend H. Vefring (photo: Rune Rolvsjord/NORCE)

About DigiWells

Digitalization, new sensors, interoperability, automation, autonomy, and improved work processes has the potential to enable a step change of the well delivery process.

The centre will explore these possibilities by combining domain knowledge with fundamental research to accelerate the digital transformation of the well delivery process.

The centre aims to develop new work processes for planning drilling and well operations, new sensors, solutions for interoperability, solutions for automated and autonomous drilling, and decision support systems for geosteering. New solutions are planned to be demonstrated, often in spin off projects, at the national research infrastructures OpenLab Drilling, Ullrigg and against field data from operators.

The centre will support collaboration between operators, service industry, public authorities, research institutions and academia in Norway and internationally. Results from the centre's activity will enable innovation, business development, and value creation for the Norwegian society. Moreover, in collaboration with universities, the centre will educate the next generation of specialists who will help implement the achieved research results.

Results from the research performed in DigiWells will be disseminated to operators, service companies, public authorities, and academic partner to enable innovation and value creation.

Partners

equinor
AkerBP
ConocoPhillips
wintershall dea
KONGSBERG
TotalEnergies
ODFJELL DRILLING
Sekal
NORCE
Lundin Energy
NTNU Norwegian University of Science and Technology
Universitetet i Stavanger
UNIVERSITETET I BERGEN
The Research Council of Norway


NORCE
OPENLAB
EPICS

Automatic Well Engineering

The digital drilling program that is being developed in DigiWells, can be a game changer towards the industry vision “plan a well in one day and with high quality”.

The goal for this epic, is to change the drilling program from today’s practice with one solution with possibly a couple of back-up plans, to an ensemble of possible drilling designs, using information from both the planning phase and the operational phase.

The workflow consists in using multiple automatic generators for each of the possible elements of the drilling program (see Fig. 1). When having all the elements in place, the digital drilling program is the combination of constraints, uncertainties, measurement strategies, operational margins, geological risks, and engineering limits that delineate an ensemble of possible drilling designs. This gives the opportunity to take well-considered choices during the planning phase, e.g., by choosing a combination of well paths, surveying programs, wellbore architectures, that give sufficient clearance to the constraints.

At the operational stage, when unexpected situations occur, acceptable margins are readily available, allowing for deviating from the plan in an informed way and without recourse to qualitative judgement.

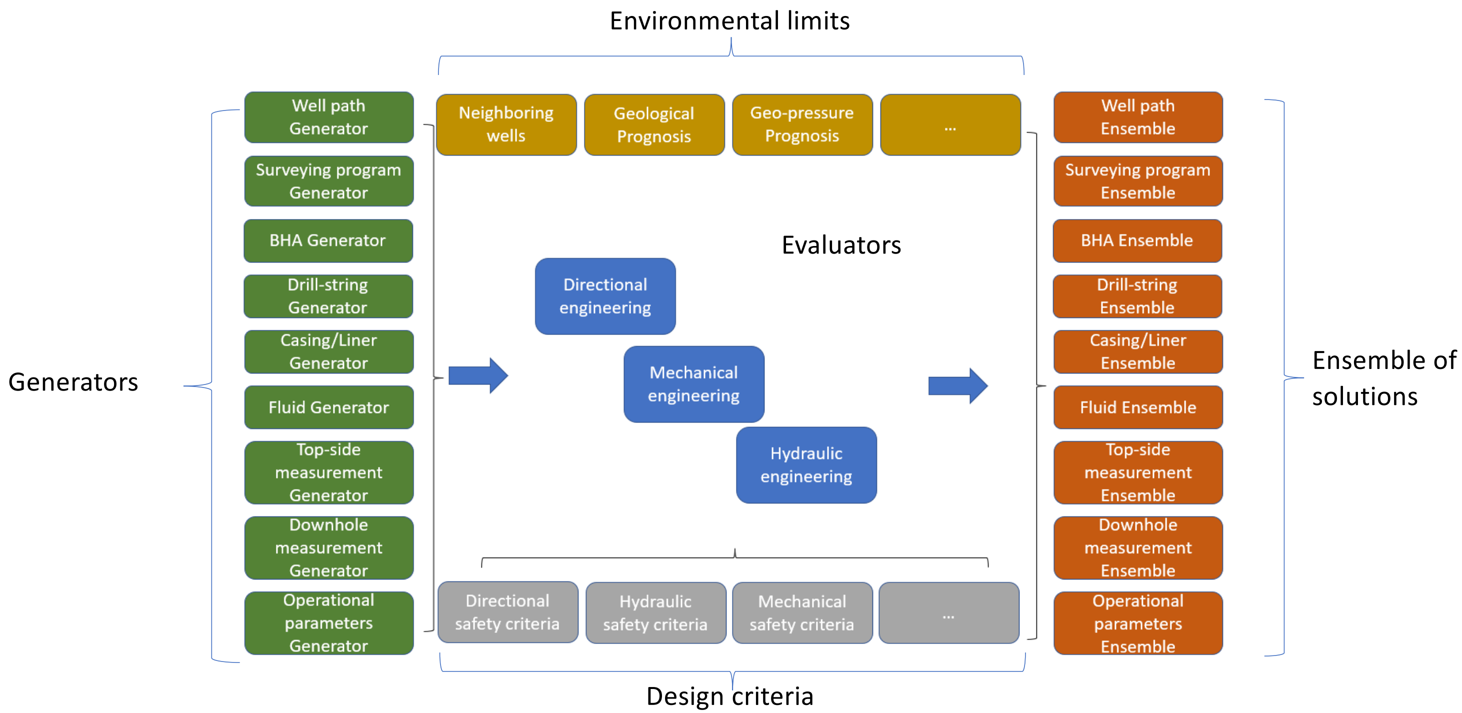

Fig. 1: Overall method

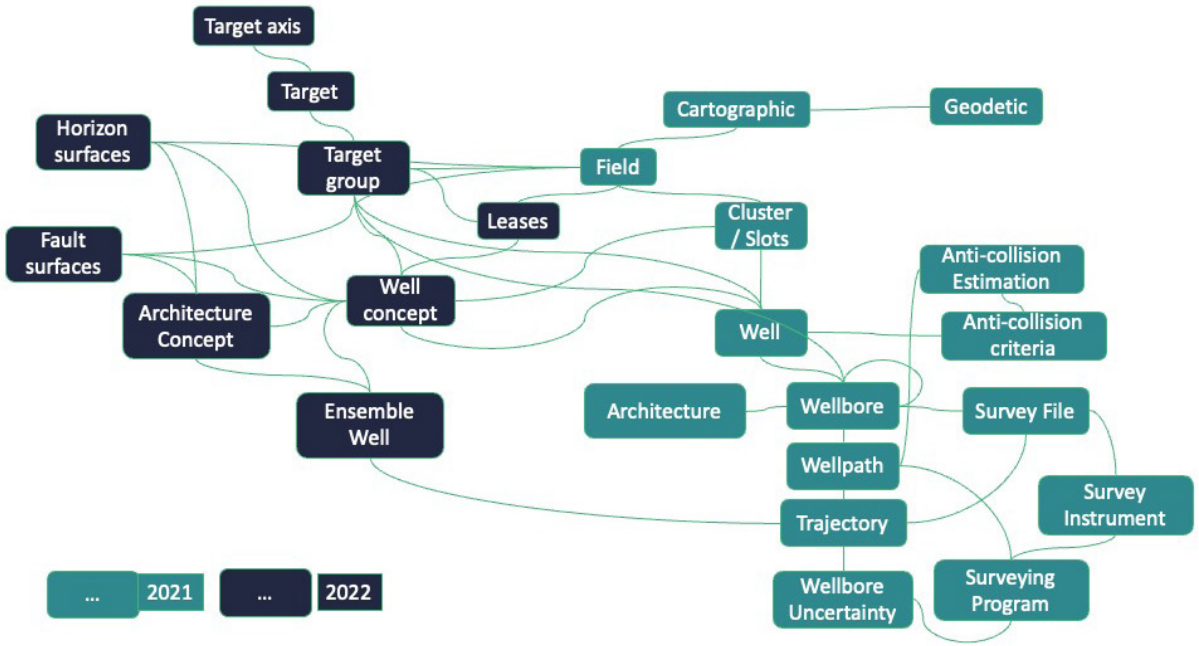

Fig. 2: Overview of the elements finalized in building the digital drilling program. The different elements are available as microservices. In 2023 new elements will be added.

Publication
Paper presented at the SPE/IADC International Drilling Conference Galveston, Texas, USA, March 2022, SPE-208791-MS:
An Ensemble-Based Solution for Automating Drilling engineering: Application to Directional Surveying by Eric Cayeux, Erik W. Dvergsnes, Liv A. Carlsen and Rodica Mihai, https://doi.org/10.2118/208791-MS

Microservice
To make it easier for the industry to do early testing of software developed in DigiWells, it has been decided to develop the solution using a microservice architecture (see Fig. 2). This architecture is composed of a collection of small services that are independently deployable and easily scalable by adding more instances of the necessary functionality. The microservices can communicate through standardized interfaces and typically adhere to the generic application programming interface (API): create, read, update, delete (CRUD). The loose connection between the microservices allows external companies to pick-up only the some microservices from the overall solution and to incorporate them within their existing software infrastructure.

An example
The focus for 2022 has been on the planned wellpath and how it is constrained by directional drilling considerations. A closer look at the elements Target and Target group will serve as an example for the method. A target is the combination of a geological body (1D, 2D or 3D) that shall be reached, and several geological bodies as horizons and faults, that should be avoided (see Fig. 3). The constraints can then be expressed as proximity distances to the bodies that shall be avoided, or alternatively penetration incident angles are this is acceptable. Uncertainties related to where these bodies are, add complexity. At the same time, the drilling program must also combine and cope with drilling engineering limits.

The digital drilling program allows for several targets to be reached either in series or in parallel like for multi-lateral wells. Individual targets are assembled in target groups that reflect the intentional use of each target, i.e., to be associated with a single wellbore or to be connected to several lateral wellbores (see Fig. 4). Both target and target groups are now available as microservices.

Further work

The work of adding more elements to the drilling program will continue in 2023. The focus will be on evaluating multiple choices for the wellbore architecture, mud program and drill-string program.

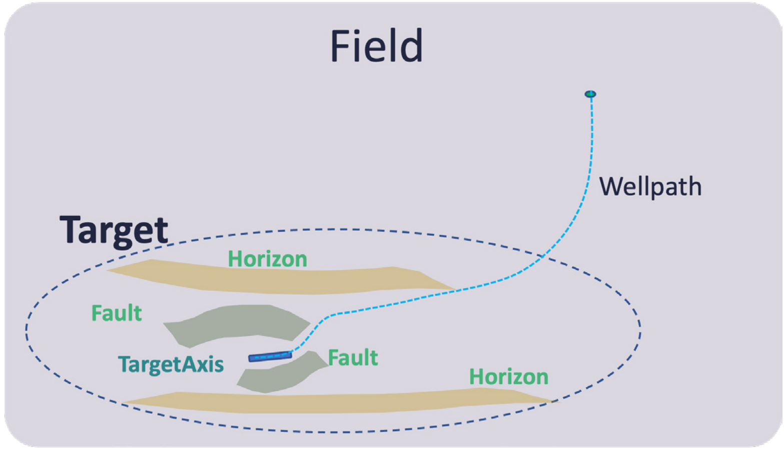

Fig. 3: Does a given wellpath reach the target or not? The aim is to hit the target in blue and avoid faults and horizons in green. The drilling program has to cope with any geological or driller's contraints.

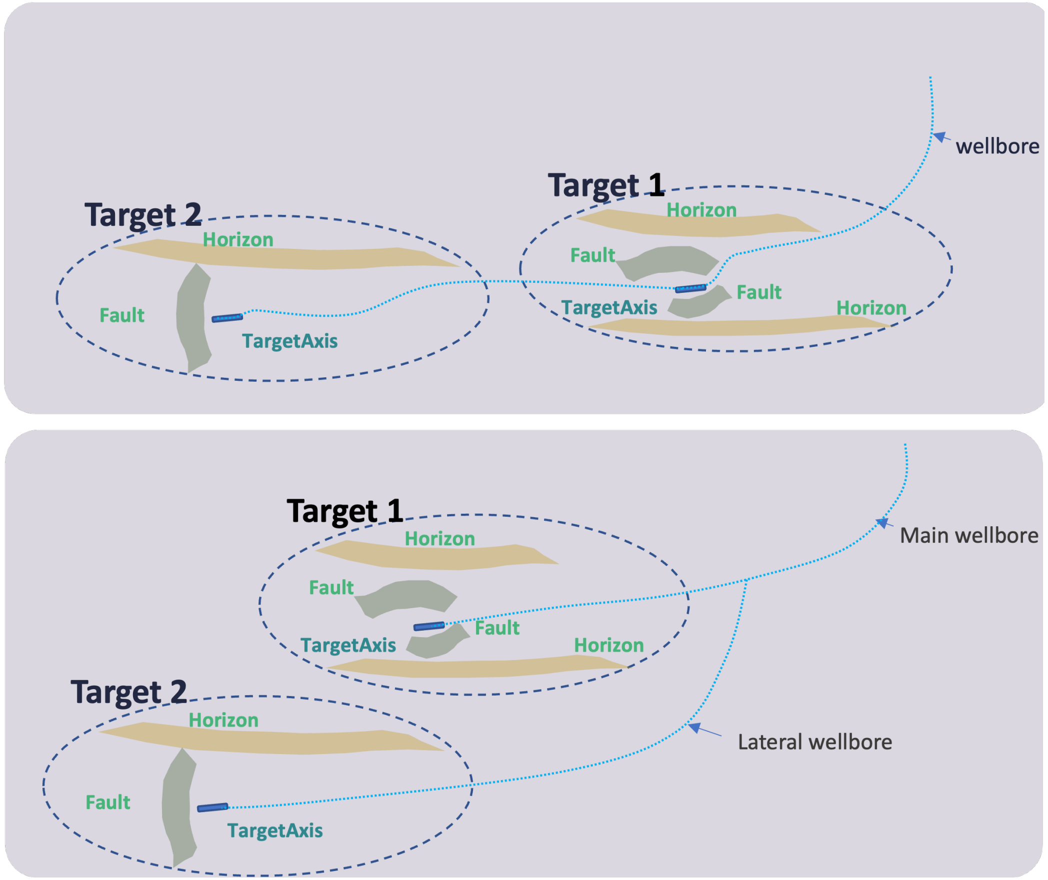

Fig. 4: Grouping of targets allows a specification for how several targets shall be reached. It can be in series where the targets must be reached by the same wellbore, or in parallel where the targets must be reached by different wellbores.

EPIC 2
Project leader:
Sergey Alyaev

Deep-learning models of drilling-process and subsurface prediction that estimate uncertainty

Optimization and decision-making during the drilling and well placement process often rely on drilling process models. These models must be fast to enable the real-time performance of optimization algorithms which often require thousands of model evaluations.
Drilling speed, also known as Rate of Penetration (ROP), directly influences the cost and energy footprint of a drilling operation. High-fidelity physics-based models are not sufficiently fast for real-time optimization. Data-driven and hybrid models enabled by machine learning have fast performance while maintaining sufficient prediction quality. However, most of them rely on a large amount of data representative of the whole operation. They do not account for uncertainty limiting their usage in the optimization context.

Our focus has been on uncertainties related to drilling performance and the geology/lithology of the drilled formations. Challenges associated with data-driven drilling performance prediction are linked to large training data requirements, lithology uncertainty, and computation cost.

Transfer learning for ROP prediction on the Norwegian Continental Shelf
Deep learning (DL) models in drilling are often limited by the diversity of training data, which may not account for sudden changes in subsurface geology and downhole conditions. For instance, when drilling two different formations, the expected ROP may differ when given a set of similar input variables.

Transfer learning is an active research field in DL that involves reusing a model trained for a more general task for another more specific task, which allows better performance with less training. Transfer learning techniques have been proven successful in many domains, such as computer vision and natural language processing, where data is expensive or hard to obtain.

In 2022, we extended the work done in the Deep Learning epic 2021 on transfer learning techniques for ROP prediction. The single transfer learning approach starts by training a base model using real or simulated data from previously drilled wells, followed by freezing some of the the model parameters and retraining the remaining parameters once using a small portion of the data from the new well. With continuous transfer learning, the pre-trained model is continuously fine-tuned on new data as it becomes available. In stateless continuous learning, the model is

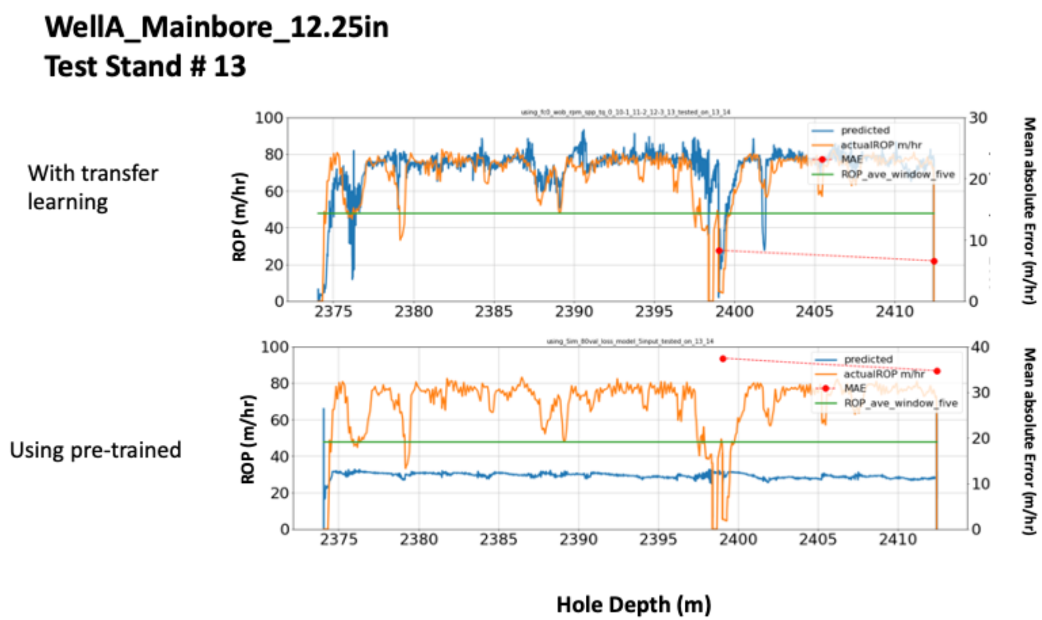

Figure 1: ROP prediction for a stand of test data. In the lower plot, the predictions in blue are made using a pre-trained model. In the upper plot, the predictions in blue are made using continuous transfer learning. The green curve represents the average ROP of the previous stand.

fine-tuned using all the data collected up to that point. In contrast, stateful continuous transfer learning only uses the most recent data.

In collaboration with AkerBP, a case study has been performed to investigate the different modes of transfer learning applied to ROP prediction. The data used for pre-training was based on several wells from the Volve field and synthetic datasets generated using the OpenLab Drilling simulator.

Fig. 1 illustrates a sample ROP prediction for a stand of test data where continuous transfer learning achieves a much lower mean absolute error (MAE) than a pre-trained model.

Our work concludes that transfer learning enables data-driven ROP modeling in a practical setting, as it reduces data and computational requirements without trading off accuracy. The continuous learning approach further reduces the ROP prediction error. It is more robust in the presence of formation changes compared to single transfer learning. Ongoing work in 2023 is focused on integrating the DL ROP prediction model and continuous retraining microservice into AkerBP's drilling data ecosystem. The transfer learning method is being further tested on both historical and live data streamed from drilling operations.

AI-based multi-modal prediction of stratigraphy to inform drilling performance

One of the main uncertainties that influence the ROP prediction is the strength of the drilled formations. Understanding the drilled rock types requires fast-streamed geophysical log processing. As log interpretations are not unique, prediction of ROP can benefit from exploring all likely interpretations and estimating their probabilities. In 2021, we developed a mixture density deep neural network (MDN) that correlates the log of the drilled well with the corresponding log from an offset well and outputs

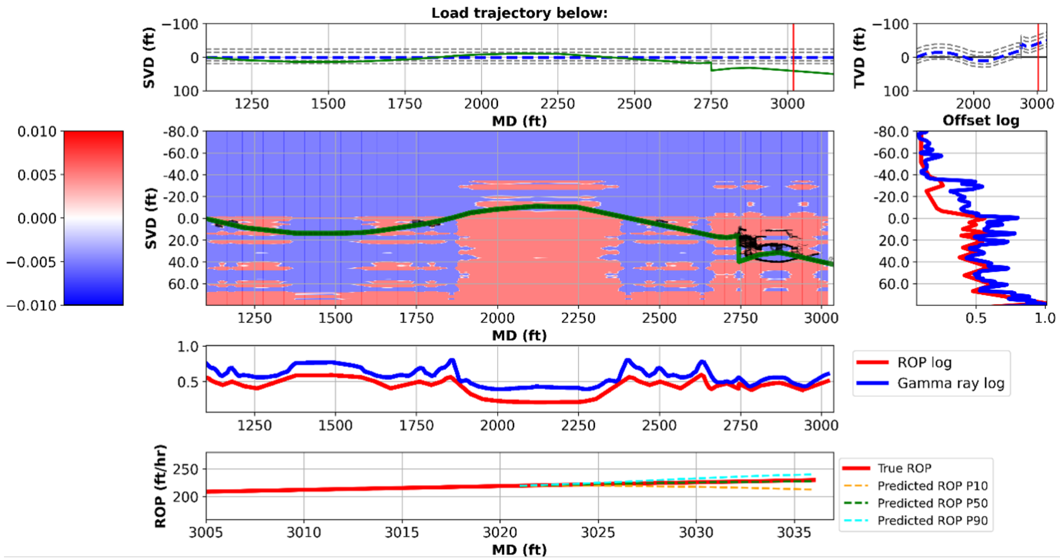

Figure 2: Interpretation for the GWC case. The outputs of the MDN are shown in black and the true stratigraphic curve in green. The bottom plot shows 16ft-ahead ROP prediction at the current interpretation step. The heat map shows the mismatch between offset and current gamma ray log.

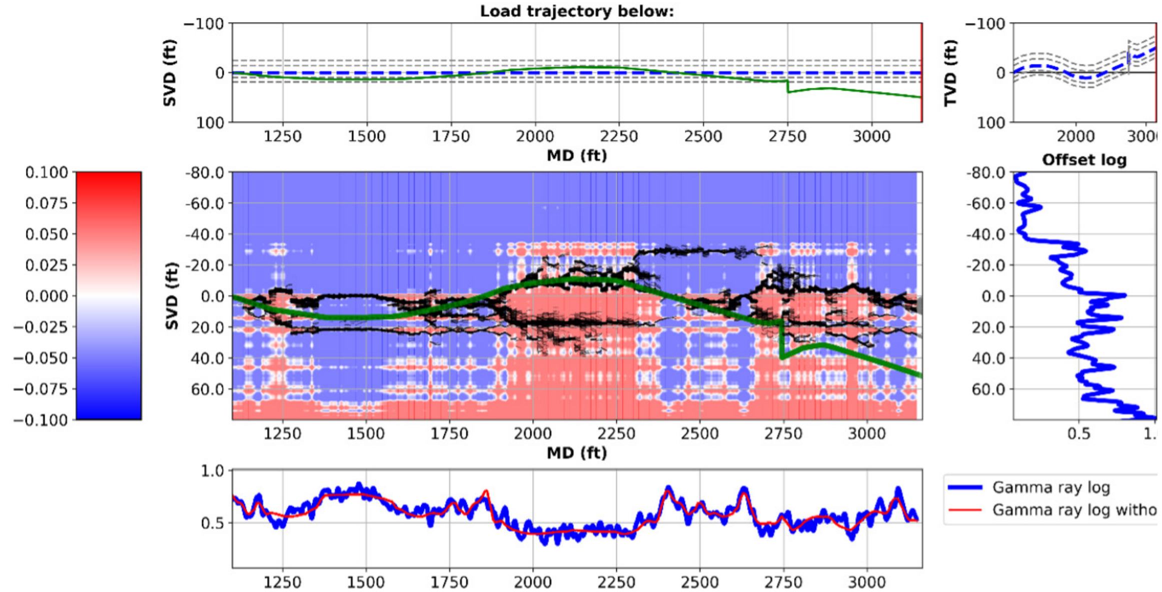

Figure 3: Interpretation for the GWC case with a noisy gamma ray log.

the most likely shapes of geological layers and their probabilities. Our MDN learns the typical configurations from the geological training data and can predict stratigraphy ahead of the bit. This work was extended in 2022 to handle inputs from several well logs and, most importantly, realistic noisy log data. With higher noise in the training data, the MDN adapts to give more “trust” to geological knowledge.

We also proposed a sequential MDN-based inversion method to track probable solutions for continuous drilling operations. The geological interpretations obtained by the method can estimate the ROP ahead of the bit and provide information about the expected drilling performance in the upcoming formations.

The method’s performance was verified on realistic well- and geological data from the Geosteering World Cup (GWC) 2020. The example in Fig. 2 shows that using gamma-ray and ROP logs as inputs, the MDN manages to track the correct solution even in the presence of a fault at 2750ft MD. The total computation time for this example was half a second on a standard PC, which is about two orders of magnitude faster than state-of-the-art stratigraphy interpretation methods. The method was also tested on noisy well logs. Fig. 3 shows the GWC case with noisy gamma-ray measurements, for which the MDN still manages to track the actual shape of geology for most of the drilled interval.

Publications

1. Transfer Learning Approach to Prediction of Rate of Penetration in Drilling. In Computational Science–ICCS 2022: 22nd International Conference, London, UK, June 21–23, 2022, Proceedings, Part II. Cham: Springer International Publishing. Authors: Felix James Pacis, Sergey Alyaev, Adrian Ambrus, Tomasz Wiktorski
2. Rate of Penetration Prediction Using Quantile Regression Deep Neural Networks. In 41st International Conference on Offshore Mechanics and Arctic Engineering, Jun 5, 2022, (Vol. 85956, p. V010T11A010). American Society of Mechanical Engineers. Authors: Adrian Ambrus, Sergey Alyaev, Nazanin Jahani, Felix James Pacis, Tomasz Wiktorski
3. Direct Multi-modal Inversion of Geophysical Logs Using Deep Learning. Earth and Space Science 9, no. 9 (2022). Authors: Sergey Alyaev, Ahmed H. Elsheikh
4. Sequential Multi-realization Probabilistic Interpretation of Well Logs and Geological Prediction by a Deep-learning Method. In SPWLA 63rd Annual Logging Symposium, Jun 10, 2022, Society of Petroleum Engineers. Authors: Sergey Alyaev, Adrian Ambrus, Nazanin Jahani, Ahmed H. Elsheikh
5. AI-based multi-modal interpretation of logs for ahead-of-bit probabilistic ROP prediction. Poster presented at the Geosteering and Formation Evaluation Workshop by NORCE and NFES, Nov. 1-2, 2022. Authors: Adrian Ambrus, Sergey Alyaev, Nazanin Jahani, Ahmed H. Elsheikh
6. Exploration of Strategies to Improve Continual Learning from Irregular Sequential Drilling Data. Accepted in 42nd International Conference on Offshore Mechanics and Arctic Engineering. Authors: Felix James Pacis, Tomasz Wiktorski, Adrian Ambrus, Sergey Alyaev

EPIC 3
Project leader:
Rodica Mihai

Reduce drillstring vibration and improve hole cleaning

Along string elements with active control can dampen shocks and vibrations, control wobbling of drillstring to improve hole cleaning and reduce the energy requirements.

Achieving optimal performance during drilling of complex well trajectories is often hindered by downhole drill string vibrations and stick-slip. These can lead to drill bit and downhole tool damage, drill string wear possibly leading to a twist-off, or formation damage. Recent advancements in drill string vibration interpretation show that the sources of excitation are not only at the bit but anywhere along the string. An innovative concept that uses distributed along-string damping elements based on magnetic damping is being developed in this DigiWells project.

Experimental work

A 10-meter-long horizontal apparatus has been constructed to mimic downhole drilling conditions. The apparatus mimics conditions such as drill string elasticity, friction forces and inertial moments to recreate real-world adverse conditions, including vibrations, stick-slip, and twist-off.

Sensors and actuators along the drill string allow to control the drill string rotational and axial velocities, contact forces at the bit and along the drill string and adjustment of the magnitude of the magnetic braking force at the sleeve.

Through the experiments performed in the laboratory setup, it was noticed that eddy current braking achieved a positive effect on damping oscillations locally in the drill string. In the field applications, the positive effect on torsional oscillations translates to an improved, more stable, ROP.

Active control of the sleeves

Passive damping has good results, but relatively large number of sleeves are required to achieve the desired effect. At the same time, slipping of the sleeve on the borehole can be a source of trouble. However, the design of the damping subs can allow for active control of the damping strength. Based on this, the current focus in the project is on how to reduce the number of sleeves by employing distributed control algorithms. Initial simulations show that is possible to achieve dampening of shocks and at the same time reduce the number of sleeves, by actively controlling the damping effect on the sleeves along the drill-string in a distributed fashion. At the same time, PhD student at NTNU, Pauline Nusse, has worked on active control of one sleeve to cope with slipping of the sleeve on the borehole.

Furthermore, active control of the sleeves can facilitate cutting transport. In addition to high flowrate and rotational speed, lateral oscillations of the drill-string on the low-side of inclined wells will improve hole cleaning. However, the drill-string lateral oscillations are usually not controlled in any way. Active control

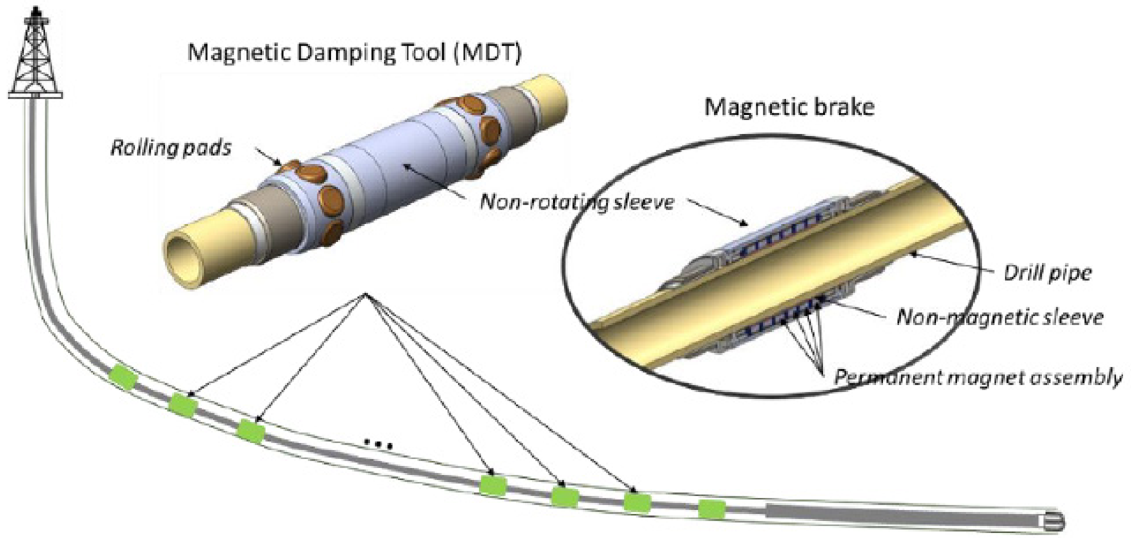

Fig 1: The proposed solution aims at dampening out stick-slip at discrete intervals along the drillstring where stick-slip originates.

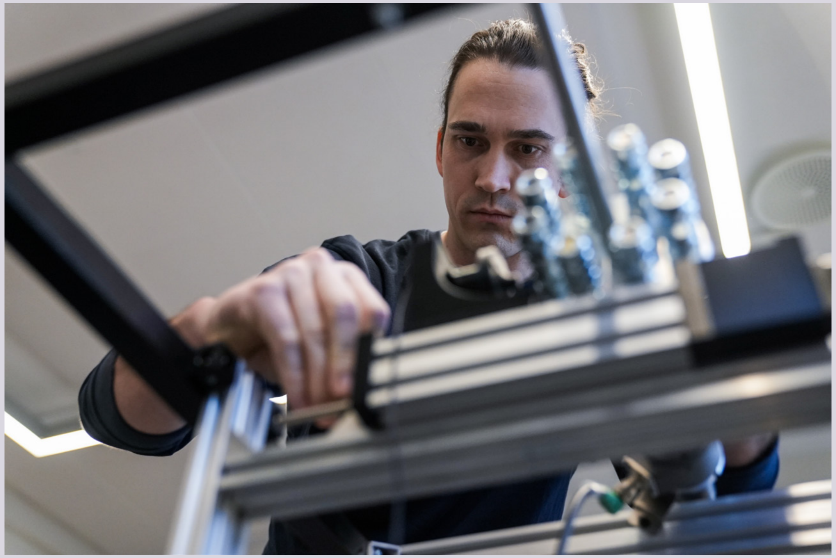
Fig 2: Andrew Holsaeter working on the experimental set-up (photo: Lisa Ravna Rørmoen/Screen Story).

of the distributed damping subs represents a solution to trigger the lateral movement of the drill-string at certain positions which can open the possibility to control wobbling of drill-string. Simulations show that it is possible to trigger different movement patterns in the drill-string by varying the damping effect of the sleeves. Work on optimization of placement and the number of sleeves will continue in 2023.

Reduction in CO2 emissions

The damping subs reduce the overall required torque at the top-drive and facilitate weight transmission to the bit. Simulations have shown that torque reduction can reach more than 50 percent. A more modest 30 percent decrease is assumed to account for the fact that the tools will not always be lying in part of the well where contacts are significant. This decrease in friction directly affects the electrical energy consumption of the top drive. When drilling long lateral sections, the savings in cost and CO2 emissions can be significant.

All directional wells will benefit from reduced vibration and reduced friction along the drill-string. Hence, the solutions developed here can bring value to most of the wells at the Norwegian Continental Shelf. For deep geothermal wells drilling in hard formation and a growing need to deploy multi-lateral well architectures, stick-slip and energy transfer are well-known issues. Finally, also P&A operations benefits from mitigate stick-slip, reduce friction, and thereby minimize their cost.

Demonstration of the concept DDHub

What: DDHub makes different players exchange information in an automatic and consistent manner.

The characterization of drilling real-time signals can happen through differentiating their names or by associating them with metadata. However, combinatorial explosion tends to limit agreement on the number of practical standardized tag names or metadata attributes. DDHub is an alternative solution to this problem. The framework defines a vocabulary of standard terms that are useful to describe facts about drilling signals. Behind this new solution, we find semantic description of real-time drilling signals in a computer readable format. DDHub allows different software solutions to discover drilling data whenever available and how they relate in terms of uncertainty propagation.

Demonstration of automatic configuration and reconciliation of three different applications

The complexity of real-time data quickly becomes apparent in the following example related to calculation of downhole pressures made available in equivalent mud weight (EMW). EMW conversion depends on references for pressure (p_0) at initial True Vertical Depth (z_0):

$$\rho_z = \frac{(p_z - p_0)}{g(z - z_0)}$$

Today, there is no unique choice for reference point for pressure calculations (p_0) and reference point for the true vertical depth of the well (z_0). It can e.g., vary with the drilling method, the domain point of view (geomechanics vs. drilling), the top-side architecture or the context change in the drilling operation. Which references that are used is often not well documented and if documented, not necessarily in a computer readable format.

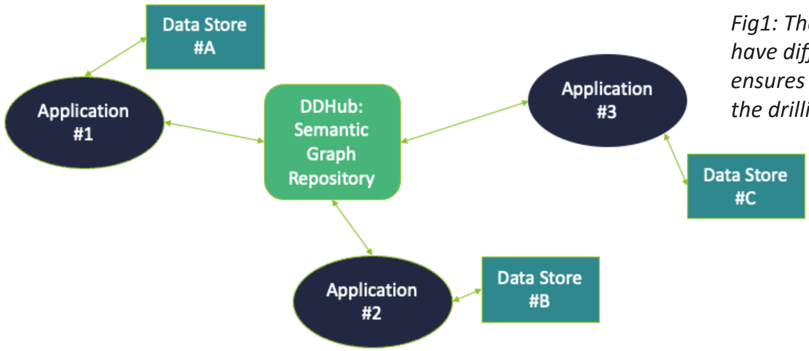

Fig1: The three different applications have different data stores, but DDHub ensures that the applications interpret the drilling data in a consistent way.

A solution to this problem consists in describing the semantics of real-time drilling signals ensuring consistency in a transparent way. The rather simple scenario of calculating EMWs from three different applications show the potential value of this solution.

The three different applications have different data stores and different reference points for pressure calculations. The context of the demonstration is conventional drilling including taking a kick while making a connection. As the context changes, exchanged information needs to be interpreted differently.

Even though the different applications utilize the "most relevant" references according to their point of view, the impact of closing the blow-out preventer (BOP) because of the influx situation, impact the conversion of downhole pressure to EMW in different ways for the three applications. However, each application shares with the others how they calculate EMW using the semantic description framework provided by DDHub and therefore can interpret the other exchanged EMW correctly. Seamless cooperation between applications working with different principles is therefore possible without necessitating human configuration. The description of the meaning of data using semantic graphs, as supported by the DDHub, brings transparency to the calculation by describing facts about drilling signals that are interpretable by computer systems.

In the paper "Interoperability of Real-time Drilling Signals at the Rig Site: An Example Based on Mechanical Specific Energy" another example considering the calculation of mechanical specific energy (MSE) in drilling (the energy required to remove one unit volume of rock) is described in detail. There is typically only a delivered value – the underlying details are lost. But with the semantic graph framework provided by DDHub allows computer interpretation of the calculation method for MSE.
The drilling industry is a multi-player operation.

However, there are large variations about how signals are measured, processed, and calculated. DDHub has the potential to lead to a standardized vocabulary that can be used by everyone.

DDHub can play an important role for speeding up automated drilling
When rigs take automated drilling into use, the drilling control systems (DCS) accept advice from external apps that includes calculations of what happens downhole. Before this can happen, extensive work on integrating apps in a safe way must be done. Different DCS vendors have different solutions for interfacing, and every rig is different. Vendors are changing, and we can easily foresee that the work necessary to configure and adapt the DCS and the external apps, can slow down the deployment of automated drilling solution because of workload and cost.

By using DDHub as an intermediate layer, once implemented, the manual work is replaced by an automated solution accommodating the different service providers with unambiguous signals. It is a flexible solution that not only handles the current picture, but also takes into account changes of vendors and measurements in the future. DDHub can potentially facilitate for more efficient deployment and further use of automation solutions.

Eric Cayeux is active in the international cross-industry group Drilling and Wells Interoperability Standards (D-WIS). D-WIS works on solutions to improve connectivity and data exchange between key equipment and systems deployed during well construction – regardless of the provider. NORCE has donated the work on DDHub to D-WIS as a possible solution to standard interfaces and to speed up the automation. At an SPE webinar, with over 500 in the digital audience, Cayeux talked about the importance of interoperability for better drilling automation.

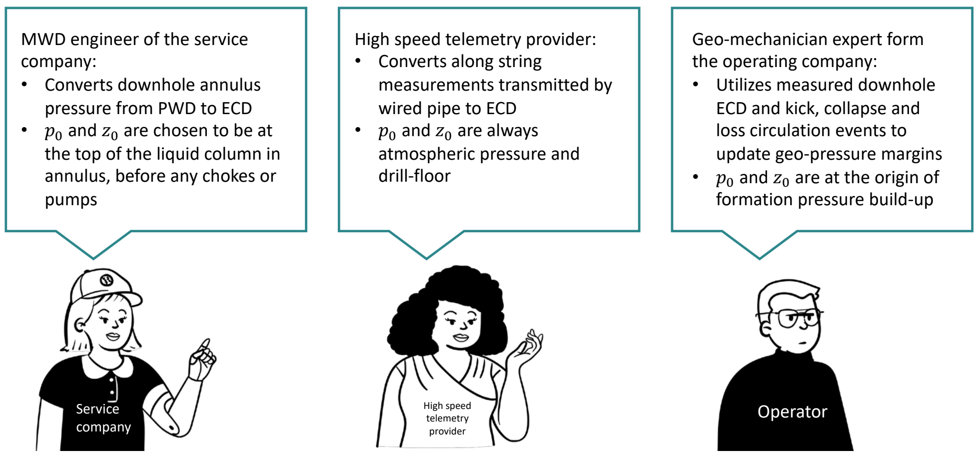

Figure 2: Many different types of drilling real-time signals are measured, processed, and generated during a drilling operation. It has been demonstrated that DDHub provides consistent EMWs adapted to the drilling operation context, and this is done seamlessly without impacting the end-users.

The Cayeux webinar is available in the following channels:

LinkedIn: https://www.linkedin.com/video/event/urn:li:ugcPost:7016488520303198208/

SPE Energy Stream: https://streaming.spe.org/spe-live-interoperability-as-a-key-factor-to-better-drilling-automation

Podcast: https://spepodcast.podbean.com/e/spe-live-podcast-interoperability-as-a-key-factor-to-better-drilling-automation/

Publications
SPE Energy Stream: https://streaming.spe.org/spe-live-interoperability-as-a-key-factor-to-better-drilling-automation

Paper SPE-212472-MS "Interoperability of Real-time Drilling Signals at the Rig Site: An Example Based on Mechanical Specific Energy" to be presented at the SPE/IADC Drilling Conference in Stavanger, Norway, March 2023

Paper SPE-212565-MS "Drilling Systems Automation: Fault Detection, Isolation and Recovery Functions for Situational Awareness" to be presented at the SPE/IADC Drilling Conference in Stavanger, Norway, March 2023

Paper SPE-212537-MS "A General Framework to Describe Drilling Process States" to be presented at the SPE/IADC Drilling Conference in Stavanger, Norway, March 2023

Method is described in paper SPE-208754-MS «A Framework to Capture the Relationships in Drilling Data and the Propagation of Uncertainty» presented at the SPE/IADC Drilling Conference in Galveston, TX, USA, March 2022

Paper SPE-208732-MS "Best Practices to Improve Accurate Time Stamping of Data at The Well Site" presented at the SPE/IADC Drilling Conference in Galveston, TX, USA, March 2022.

Presentation "Drilling Data Quality and Uncertainty" at the SPE-WPTS ISCWSA conference (virtual) April 14, 2021

Presentation "The Role of Software Interoperability to Improve Performance and Quality of Service in Drilling Operations" at the SPE Virtual Workshop Asia Pacific Digital Week – "enhancing the energy value chain through Innovation and digital ecosystem", 9-11 Nov. 2021.

Photo: Helga Gjeraldstveit

DigiWells annual seminar

The annual SFI DigiWells seminar brought together experts from industry, academia, regulatory bodies, interest organizations, and clusters. We had cutting edge presentations on digitization and automation for drilling and well and provided a broad forum for discussions and networking.

Chairman of the Board, Halvor Kjørholt, Equinor, stated that: - Only digital and automated solutions can modernize drilling and bring performance to a modern industry level.

Researchers from DigiWells held presentations at the seminar. From left to right:

- *Sergey Alyalev presented an AI-based model that can predict stratigraphy and thereby improve drilling performance.*
- *Eric Cayeux held a presentation on the differences between automated and autonomous operations.*
- *Rodica Mihai presented autonomous drilling demonstrated at Ullrigg.*
- *Benoit Daireaux. presented our extensive work on data and interoperability.*

Interesting questions from the audience. Here represented by Marianne Høie, Equinor.

All photos: Rune Rolvsjord, NORCE

- It might be too late for this year, but I already know what I want for next Christmas. It is a big present - autonomous operations. I hope DigiWells can help make that dream come true.
Erik G. Kirkemo, SVP of Drilling & Well at Equinor.

Arnfinn Grøtte from AkerBP talked about collaborative well planning. With around 150 software applications for subsurface available in AkerBP, he emphasized the importance of plug-in apps.

All photos: Rune Rolvsjord, NORCE

Cayeux awarded SPE Drilling Award

NORCE's Chief Scientist Eric Cayeux was awarded the International Drilling Award for 2022. The prize goes to persons who have made significant technical and professional contributions to the industry, and the Society of Petroleum Engineers (SPE) gives the award.

The awarding is a great recognition of Cayeux's extensive work over many years, and Cayeux received the prize at the ATCE Annual Awards Banquet in Houston, Texas on the 6th of October.

In their press release, SPE recognised Cayeux for his key development of the widely used DrillScene and DrillTronics products, his many patents, and his deep understanding of the practical and technical details of drilling operations, mathematical modelling, experiments, and software development.

- It is an honor to recognize Eric for his commitment and dedication to the oil and gas industry with the SPE Drilling Engineering Award. SPE international award winners were nominated by their colleagues and selected by their peers for their achievement and contributions. It's my pleasure to congratulate Eric on receiving this prestigious international award from SPE," said Kamel Ben-Naceur, 2022 SPE President at the awards banquet.

DigiWells' centre director Erlend Vefring congratulates Cayeux on his award.

- We are very proud of our Chief Scientist. Having a world-leading researcher in DigiWells helps to ensure a high level of research, and he is important for a leading research environment in drilling, says Vefring.

Photo: The Society of Petroleum Engineers (SPE))

From automated drilling to autonomous drilling

For automated drilling, the driller can start automated sequences such as a friction test. For an autonomous system the system itself makes the decisions while the driller observes what is happening.

Different players have different views on what autonomous drilling is. In order to have a common understanding, Eric Cayeux presented a roadmap to autonomous drilling at the DigiWells' annual seminar. The way of classifying automated and autonomous are with references to D-WIS and A Logical Approach*. In that context, an automation drilling system is autonomous when it is flexible to changing environments and changing goals, learns from experience, and makes appropriate choices given perceptual limitations and finite computations.

Here is an explanation for what it takes to move from an automated system to an autonomous system (see Fig. 1, Fig. 2, Fig. 3).

Machine Control
The innermost layers, execution levels 5 to 8, are linked to the drilling control system on the rig which contains among other things sensors that measure inputs and outputs of the machines and make sure that no machines collide.

Automated Drilling
Automated drilling involves different types of functions, execution levels 1 to 4:
Fault Detection, Isolation and Recovery (FDIR) is a subfield of control engineering concerned with monitoring a system, identifying when a fault has occurred, and determining the type of fault and its location. After detection, actions are taken to isolate/mitigate the fault. Fault recovery is the action taken after a failure has been detected and isolated to return the system to a stable state. An example from drilling can be detection and reaction when moving the drillstring and having an overpull. The hook load overpasses the threshold and an automatic action is taken to mitigate the overpull and return the drilling system to a stable state.

Safe Operating Envelope (SOE) means that the range of parameters is limited to keep the operation within the margins of the well. As an example, the max flowrate limit during a drilling operation to avoid fracturing the open hole formation depends on the axial and rotational velocity of the drillstring and the context such as the bit depth, fluid properties and downhole temperature.

The aim of closed loop control is to manipulate a variable such that a process variable is as close as possible to a desired value, often called a set-point. In drilling it can be an auto-driller that maintain a constant rate of penetration (ROP). The ROP varies with formation and bit wear, but with feedback-control, the auto-driller tries to keep the ROP as close as possible to the set-point.

Dynamic standard drilling procedures are control mechanism designed to automatically follow a sequence of operations or respond to predetermined instructions. An example is a friction test. The friction test has a sequence of operations that can be initiated by the driller and performed automatically. It depends on the current context like for example the length of the drill-string and its elasticity as well as the flow conditions.

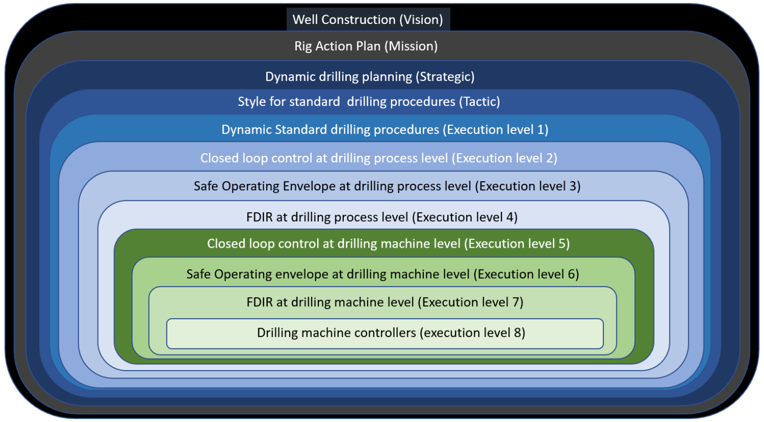

Fig. 1: Hierarchical control architecture. Decisions flow from top to bottom while information flow from bottom to top. If a system includes execution levels 1 to 8, it is an automated system. In an autonomous system you also need to coordinate the execution levels. An autonomous system can be achieved by a hierarchical control architecture that includes Vision, Mission, Strategy and Tactic.

Autonomous Drilling
DrillTronics, commercialized by Sekal, is an example of an automatic drilling control system with fully automated agents, as illustrated by the red frame in Fig. 2. To reach autonomy, the automated agents need to be coordinated as part of online decisions taken by the system. This can be achieved by using a hierarchical control architecture that includes Tactical, Strategical, Mission and Vision levels. Reaching autonomous control means that real-time decisions are taken in view of the current context by the system without human interaction.

Autonomous drilling as a real-time optimization problem
Obviously, drilling should be as fast as possible, the weight-to-weight procedure should be as short as possible and quick pipe handling

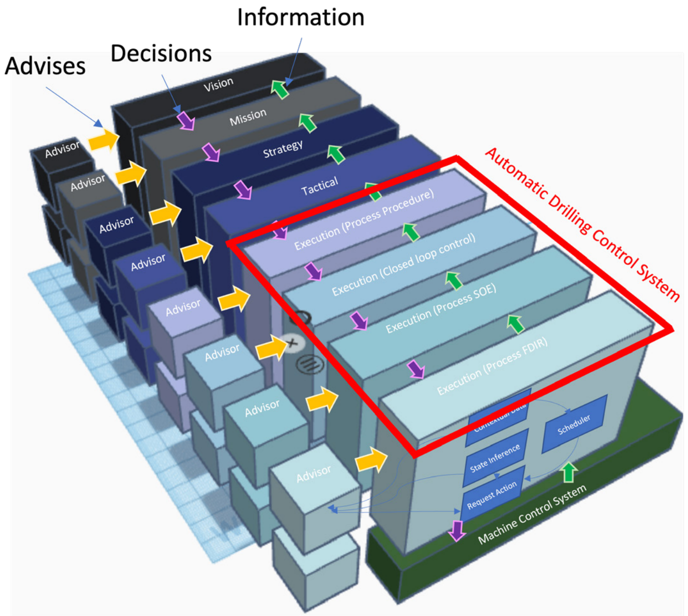

Fig. 2: Decisions flow from top to bottom while information flows from bottom to top. The level of abstraction for decisions and information is more and more concrete when going down the hierarchy. Advisors provide input to decision making and information interpretation for each level in the hierarchy.

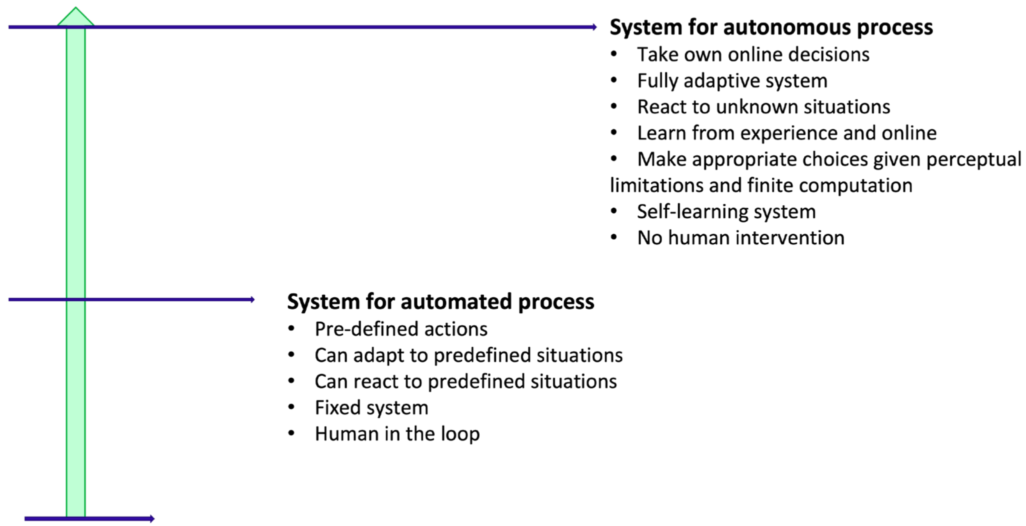

Fig. 3: An autonomous drilling system takes the responsibility of strategic decisions in a multi-horizon time perspective and executes the necessary actions to perform the strategic plan.

shall be made during connection. At the same time, it is important to avoid unwanted situations like pack-off, hole collapse, stuck pipe, and many more. Actions need to be taken by the autonomous system in a multiple time-horizon perspective, both short, medium and long term, while at the same time trying to reach the end goal. It is a real-time optimization problem! The solution used for online decision making by the autonomous system is based on the Markov Decision Process framework.

In 2021 NORCE demonstrated fully autonomous drilling at the full-scale offshore-type rig, Ullrigg, in Stavanger. 500 meters were drilled without interaction from the driller. The autonomous drilling system made all the decisions. To continue the work with autonomous drilling solutions, the DigiWells operators support an application on Autonomous Tripping that is submitted to the Research Council of Norway's Petromaks program. Fingers crossed for another spin-off project!

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2. 2. E. Cayeux, B. Daireaux, A. Ambrus, R. Mihai, and L. Carlsen, "Autonomous Decision-Making While Drilling," Energies, vol. 14, no. 4, p. 969, Feb. 2021, https://doi.org/10.3390/en14040969

3. 3. R. Mihai, E. Cayeux, B. Daireaux, A. Ambrus, P. Simensen, M. Welmer, M. Jackson, "Demonstration Of Autonomous Drilling On A Full-scale Test Rig," https://doi.org/10.2118/210229-MS

4. 4. E. Cayeux, J.D. Macpherson, M. Laing, D. Pirovolou, F. Florence, "Drilling Systems Automation: Fault Detection, Isolation and Recovery Functions for Situational Awareness", https://doi.org/10.2118/212565-MS

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DigiWells contributor to AI in Energy

The research in DigiWells tackles complex challenges in highly dynamic environments through Artificial Intelligence (AI) techniques.

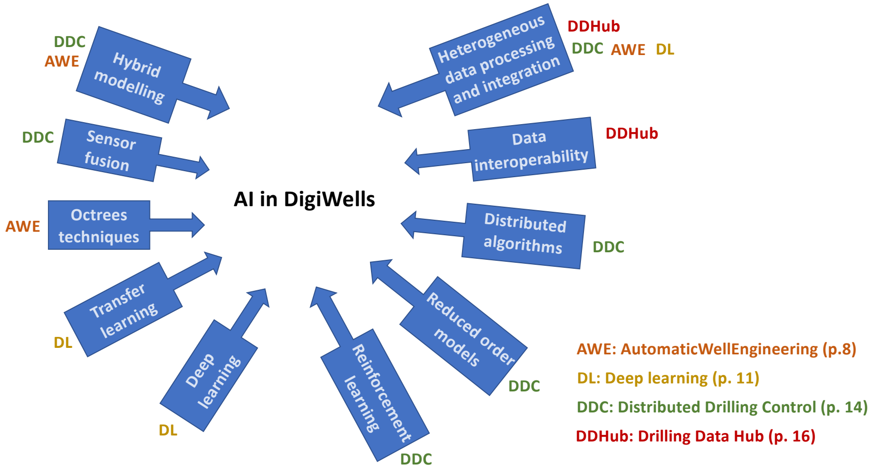


Figure 1: Overview examples AI techniques and solutions in DigiWells

While AI is much referred to during the last years, various meanings are considered behind the wording. We briefly present here some of the AI techniques and challenges addressed in DigiWells. Well construction is a complex process where many unexpected events can occur at any time and where limited real-time measurements are available, with their quality varying. Hence, developing AI systems to automate the process is a difficult task which involves sophisticated algorithmic techniques to cope with delays, uncertainties, availability of data and the complexity of the processes involved. Some of the important aspects that the AI research in DigiWells is covering are dynamic context, safety of the process, criticality of the process and level of human involvement in the decision-making. For instance, safety of the process includes both safety of the system and safety of the environment, and features such as fault detection, isolation and recovery and safe operation envelopes are important to ensure a safe behavior of the AI system [ref. roadmap section, p. 22]. That an operator develops trust in the system is crucial for the adoption of AI systems developed in DigiWells. This includes trusting that the AI algorithm makes the correct decision under the correct assumption, that it is possible to understand what happened when the AI algorithm failed and that the predictions from the AI system are in line with expectations. Information that the AI algorithm performs badly on a specific set of data is very useful and generally, thorough knowledge of limitations of AI techniques is important for both the design and implementation in the field of an AI system, hence its inclusion in the research in DigiWells. In Figure 1, some concrete examples are presented for the digital systems and solutions provided by DigiWells that are covering different aspects of the well construction and which are using several different algorithmic AI techniques.

The research results in DigiWells are made available through the scientific publications, referenced in the report. In addition, several presentations were given by the researchers in the center to a broader forum, also outside drilling community. Particularly, sharing on research results and competence of the team in DigiWells with younger researchers was focused upon in DigiWells. Such examples include an invited presentation at Nordic AI Meet 2023 (Nordic Young Researchers Symposium) organized by NORA (Norwegian Artificial Intelligence Consortium) with CLAIRE (Confederation of Laboratories for Artificial Intelligence Research in Europe) and Research Council of Norway as main partners. Another example is a guest lecture on sharing competence from the research on AI system in practice at BI Norwegian Business School in the course: “AI, Algorithms and Society”.

R. Mihai, “Autonomous drilling: example of an AI system in practice, Guest lecture at BI Norwegian Business School, 2022

Six months at Stanford

Ressi Bonti Muhammad had a six month long stay at Stanford University while working on his Ph.D in drilling and geosteering.

- I feel incredibly fortunate to have had the opportunity to attend Stanford, which consistently ranks among the world's top academic institutions. I received a world-class education in Applied and Computational Mathematics and connected with an incredibly diverse community of individuals from all over the world.

Ressi worked with Professor Daniel Tartakovsky and his research group in the Department of Energy Science and Engineering.
- Their deep expertise and innovative approach to problem-solving gave me a new perspective on my work and helped me achieve breakthroughs that I never thought possible.

Ressi's Ph.D. aims to develop and improve a decision support system (DSS) that provides optimization-based decisions under geological uncertainty during drilling and geosteering. He describes it like this:
- A drilling operation and geosteering are like navigating through a pitch-black road with only the car dashboard as your guide. You have some information about where you've been, but the path ahead is shrouded in uncertainty. Geosteering takes this concept underground, where navigating complex geological formations is a constant challenge. That's where my Ph.D. project comes in.

By developing new tools and techniques that can utilize all available information, Ressi's goal is to help geosteering professionals make more informed decisions and improve the chances of success. One of the main goals of the project is to use reinforcement learning (RL) algorithm for the DSS.
- Previous research in this area has typically relied on traditional decision-making algorithms. We sought to employ a novel approach that has shown considerable promise in addressing sequential decision-making problems. RL has outperformed human decision-making on various problem domains, for example when beating expert gamers at classic ATARI games, which is all about making the right decisions.

By utilizing RL we aim to evaluate its effectiveness in comparison to the expertise of geosteering professionals.

At Stanford Ressi met a research group with world-class expertise within applied mathematics.
- Mathematics has always been a driving force in my academic pursuits, so I was thrilled to work alongside the research group. We applied their research to the world of drilling and geosteering, where the power of mathematics and problem-solving can have a tremendous impact.

Working with colleagues from different fields can be a challenge, especially when it comes to finding common ground. Ressi and his colleagues had to navigate different knowledge backgrounds to find a way to work together.
- Ultimately, we hit upon an ingenious solution: we adapted one of Stanford students' research projects on Particle Filters and used it to create a powerful tool for reducing subsurface uncertainties. It strengthened our professional relationship and left me feeling energized and inspired for the possibilities of future collaborations.

Now Ressi and his colleagues are working towards publishing a joint paper on their results in 2023.

Ressi Bonti Muhammad is one of five Ph.D. students connected to DigiWells. He has his master's in petroleum engineering from NTNU, and his BSc from Bandung Institute of Technology. Now he is halfway through his PhD at the University of Stavanger, with Reidar Brumer Bratvold as his supervisor, and Sergey Alyaev from NORCE and DigiWells as his co-supervisor.

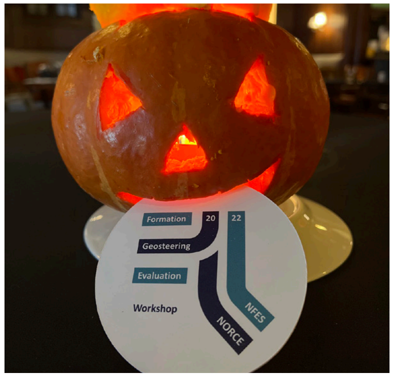
Geosteering and Formation Workshop

In November NORCE and the Norwegian Formation Evaluation Society (NFES) hosted a two-day Geosteering and Formation Workshop at Sola Strand Hotel in Stavanger. The Workshop gathered participants from France, Italy, Spain, Turkey, the UK, Thailand, the USA, and from all over Norway.

Pete Heavy, Co-lead of the Geosteering Network in Aker BP, held the opening keynote. He spoke about cooperation.

– Fail with pride, as a team. Operators are the key driving force. Technology partners are the key enablers and agents of improvement.
– With his opening statement, Pete set the intended spirit for the whole event: collaboration, says Sergey Alyaev, the main organizer of the event and senior researcher at NORCE and DigiWells:
- Bridging academia and different sectors of the subsurface industry was one of our primary goals for the workshop.
I am glad to see that the workshop fulfilled the target objectives: Participants from research told us that we presented them with new industrial challenges, while industrial experts saw potential for innovation projects based on the new research.

All photos: Rune Rolvsjord/NORCE



3D-GIG – 3D Geological Interpretation for Geosteering of wells

An application on the topic geosteering and supported by the operators in DigiWells, was submitted and awarded by the Research Council of Norway in 2022.

Geosteering decisions are based on geological models. To make optimal decisions while drilling, it is necessary that geological models for the near-wellbore region are well-calibrated against measurements received while drilling, and that uncertainties are quantified. The current work processes for geosteering suffer from shortcomings:

1. It is highly challenging to geologically interpret Logging While Drilling (LWD) measurements in real-time for complex formations in an objective manner.
2. It is highly challenging to update geomodels from available interpretations.
3. There is a lack of a transparent, systematic, consistent and effective workflow for quantifying complex geological uncertainties.

The primary objective of this project is to establish and verify a workflow for automatic, real-time, objective around bit 3D geological interpretation of LWD logs for optimal well placement decision support while drilling in complex formations. The format of the interpretation supports future automatic updates of standard probabilistic geomodels.

The scope is very much in line with SFI DigiWells' goal of automatic geosteering and will be an important step towards a workflow for automatic, real-time around-bit 3D geological interpretation of LWD logs, including deep sensing Electro-Magnetic (EM) logs for optimal well-placement decision support while drilling in complex formations. The project will start in 2023 and is a collaboration with the University of Stavanger and the University of Texas at Austin.

Project leader: Nazanin Jahani, NORCE

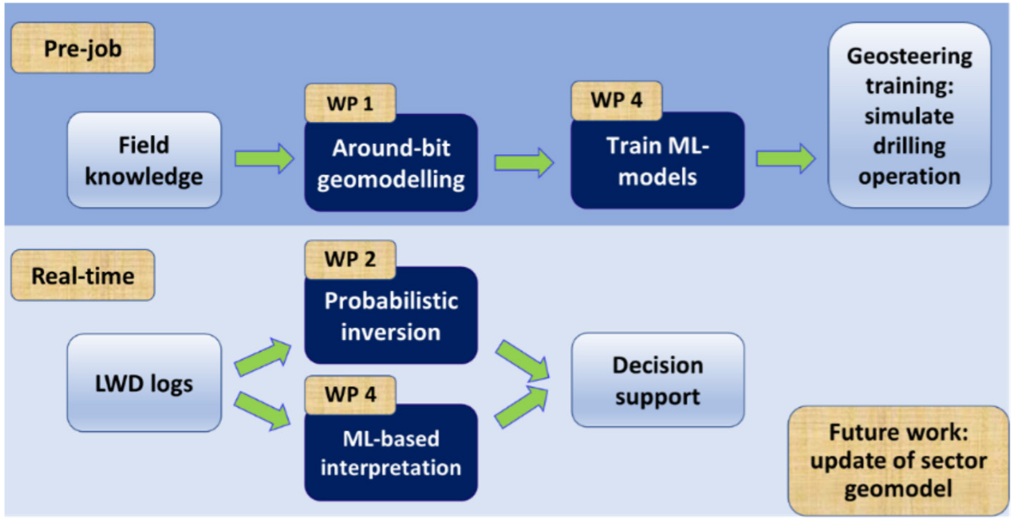


Fig: Planned workflow, work packages (WP) are indicated. Top: pre-job phase with model construction and training of geosteering personnel. Bottom: real-time phase with geosteering decisions supported by around-BHA geological interpretation. In the future, the sector geomodel could be automatically updated to enable decision support based on automatic ahead-of-bit geological forecasts.

Flowrate Out Sensor

To remove the bottleneck associated with the flow paddle, a new flow rate out sensor is suggested with an accuracy of 1 %, making it a game-changer for drilling operations and potentially revolutionizing the drilling industry.

The Macondo blowout in 2010 was caused by a series of events, and a main critical factor was the lack of accurate flow measurement as pointed out in the investigation that followed. The commonly used measurement device, the flow paddle, used on Deepwater Horizon, has an accuracy of 10 %. This technology is still preferred due to the lack of alternatives.

A flowmeter comprising a mass flowmeter and a density measuring apparatus Initial research using a small-scale apparatus has verified the measurement principle and is applicability for drilling operations, with the required accuracy. The innovation includes sensors for measuring cuttings rate, cutting size distribution, and gas content making it a multi-measurement device requested by the drilling industry for decades. A patent has been granted for Norway in 2021. An international patent application, PCT, is in process.

NORCE has now been awarded a verification project by the Research Council where the main objective is to verify that a semi-full-scale sensor (max 1000 liters per minute (L/min)) has the required sensitivity and precision, with an error at 1% or lower, and with a design that fits existing flowline on representative offshore drilling rigs.

It will be exciting to follow this project which will start in 2023!

Project leader: Jan Einar Gravdal

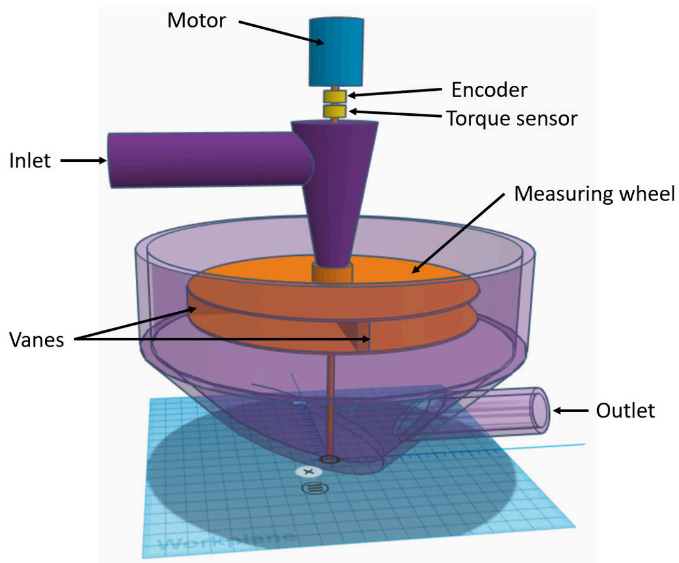


Fig: Schematic of the flowmeter and its components

Photo: Lisa Ravna Rørmoen/Screen Story

Centre management

Erlend H. Vefring
SFI Director

WP7 - Project management

Helga Gjeraldstveit
SFI Assistant Director

WP6 - Studies and analysis

Sergey Alyaev
WP-leader

WP1 - Agile well construction work-flow

WP2 - Predictive modelling

Eric Cayeux
WP-leader

WP3 - Smart sensing

WP4 - Interopera-bility and user-sys-tem interaction

Rodica G. Mihai
WP-leader

WP5 - Drilling auto-mation and auton-omy

Mette Stokseth Myhre
Administrative coordinator

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as of 31.12.22

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Øystein Arild, University of Stavanger

Morten Jakobsen, University of Bergen

Ole Morten Aamo, Norwegian University of Science and Technology (NTNU)

Aina M. Berg, NORCE AS

Espen Forsberg Holmstrøm, Research Council of Norway (Observer)

From left to right, Tron Golder Kristiansen, Anar Ismayilov, Aina M. Berg, Halvor Kjørholt and Tron Helgesen (Photo: Rune Rolvsjord, NORCE)

PhD students

Ressi Bonti Muhammad

PhD topic: Sequential decision analysis in drilling and geosteering

Affiliation:	**University of Stavanger**
Supervisor:	**Reidar Brumer Bratvold**
Co-Supervisor:	**Sergey Alyaev**
Associated Epic:	**Real-time decision making in drilling and geosteering**
Period:	**2021-2024**

I come from Indonesia. My BSc is from Bandung Institute of Technology in Petroleum engineering. I recently graduated and earned my master's degree from NTNU, also in Petroleum engineering.

We have worked on proposing the use of Reinforcement Learning (RL) to optimize two published geosteering decision-making problems by building an RL-based decision support system. The results indicate that the RL approach outperforms the commonly used greedy optimization method and is comparable in performance to the approximate dynamic programming method while being more robust and computationally efficient. This work has the potential to improve the efficiency and accuracy of geosteering decision-making and reduce computational costs.

The current project involves collaborating with colleagues from Stanford University to develop the RL-based decision support system further. The aim is to extend the system's capabilities to support a more complex case than the previous two to provide even more accurate and efficient geosteering decision-making. Through this collaboration, the team hopes to push the boundaries of what is currently possible in geosteering and contribute to advancements in the field of decision support systems more broadly.

Felix James Cardano Pacis

PhD topic: Online / Offline Deep learning models

Affiliation:	**University of Stavanger**
Supervisor:	**Tomasz Wiktorski**
Co-Supervisor:	**Sergey Alyaev**
Associated Epic:	**Deep learning for drilling models**
Period:	**2021 – 2024**

Felix is a Ph.D. student in Deep Learning at UiS where he also finished his master's degree in drilling and well engineering. He also has a BSc degree in Petroleum Engineering from Palawan State University.

The main objective of their project is to leverage Artificial Intelligence (AI) to build adaptive data-driven models for drilling and positioning wells. Addressing the practical bottlenecks of data-driven models for field implementation is also part of their research.

To achieve their objectives, they explored the application of transfer learning in ROP prediction. Simulated data using NORCE's OpenLab and real well data from the industry partners were used to pre-train models. Subsequently, these pre-trained models were fine-tuned with varying retraining data percentages from other wells. Initial results showed that transfer learning reduced computational costs and training time. In addition, the group observed that simulated data could be used in the absence of real data or in combination with real data to train a model without trading off the model's predictive capability.

The group is also working towards an adaptive ROP predictive model that provides expected ROP values in response to surface drilling parameters and formation properties. Since all factors affecting the drilling rate are not always known prior to drilling, the group is currently investigating the optimal fine-tuning configurations that would allow us to recalibrate the model as frequently as possible in real-time operations. This is a necessary step towards a data-driven ROP optimization that would directly translate to cost savings and emission reductions.

Luis Saavedra Jerez

PhD topic: Impact of the expected measurement quality and uncertainty while working on the engineering of a well

Affiliation: University of Stavanger
Supervisor: Dan Sui
Co-Supervisor: Eric Cayeux
Associated Epic: Automated Drilling Engineering
Period: 2021 - 2024

I got my bachelor's degree in Petroleum Engineering and Natural Gas in Bolivia (2018). I received my master's in drilling and well engineering at the University of Stavanger (UiS) in 2021. During my master's, I led the winning DrillBotics team for the Virtual Rig part. I was also awarded excellent academic performance at UiS.

My study focuses on analyzing the effects of uncertainty on parameters at the moment of making a drilling plan. Not knowing what will be found later carries some risks. Considering another alternative plan may lower the risk of finding further troubles.

Currently, I have developed and explored the application of a curve with constant curvature and constant toolface in the trajectory design to reduce the uncertainty linked with the difficulties of following the planned path.

Moreover, the next part of my study will focus on the statistical physics adapted to the forecast of the geo-pressure window in the drilling plan. The window is a fundamental part of establishing a safe range of the formation pressures that strongly influence the rest of the drilling plan.

Pauline Nüsse

PhD topic: Automatic control of sleeves for damping of drill-string vibrations

Affiliation: NTNU
Supervisor: Ole Morten Aamo
Co-Supervisor: Adrian Ambrus
Associated Epic: Distributed Drilling Control
Period: 2021-2024

The main objective of my thesis is to actively control the sleeves developed in this epic to allow a more efficient way of drilling.

The goal is to reduce vibrations and minimize energy consumption. Several sleeves can be placed along the drill string at the positions with the largest side forces, to maximize the reduction of mechanical friction along the wellbore. To show the positive effects of using active sleeves, subs with only local knowledge are used in the first place.

To prevent the sleeves from slipping an On-Off based control scheme is implemented. Stability maps allow a comparison of the stick-slip mitigation abilities of this controller and the passive sleeves for a broad range of top drive feed rates and RPM.

Marios Gkionosz

PhD topic: Extremum seeking control using ideas from reinforcement learning

Affiliation: NTNU
Supervisor: Ole Morten Aamo
Co-Supervisors: Bjarne Andre Grimstad, John-Morten Godhavn, Ulf Jacob Flø Aarsnes
Associated Epic: Distributed Drilling Control
Period: 2022 - 2025

I am educated in Mechanical Engineering (received my Integrated Master's degree with honors from the Aristotle University of Thessaloniki, Greece in 2020). I hold experience in dynamics simulations and NMPC control.

The goal of the PhD project is to develop Real-Time optimization control algorithms that improve the performance of traditional Extremum Seeking Control (ESC) by combining it with algorithms from the Machine Learning family. It is expected that this extension will result in the ability to identify optimal dither signals for high-dimensional systems so that faster convergence can be achieved with reduced excitation using stored data.

Using state-of-the-art implementations, the approach is to connect known shortcomings of ESC with Reinforcement Learning and/or Deep Learning and formulate new implementations. The new and improved algorithms will be tested and demonstrated on applications of relevance to the DigiWells partners.

Durra Handri Saputera

PhD topic: Borehole electromagnetic modeling and inversion

Affiliation: University of Bergen
Supervisor: Morten Jakobsen
Co-Supervisors: Sergey Alyaev, Nazanin Jahani, Kjersti Solberg Eikrem
Associated Epic: Real-time geophysical data imaging while drilling
Period: 2022-2025

I have a keen interest in modeling geophysical data. I graduated from Idea League joint master program in Applied Geophysics, which is held at TU Delft, ETH Zurich and RWTH Aachen, and I worked on electromagnetic induction inversion in my master thesis.

In this project, I will be working on borehole electromagnetic induction tool data inversion to provide the subsurface image around the borehole during the drilling process. I have successfully implemented 3D forward modelling with integral equation method on GPU, which enables up to an order of magnitude speed up in computation time. Currently, I am working on investigating the domain decomposition method in integral equation method for further speeding up the computation time.

After finishing the development of forward modelling, I will explore different parameterization and algorithm that can be used for stochastic inversion to quantify uncertainty. In addition, I am going to study the effect of anisotropy in the inversion. Data-driven method such as physics-based machine learning is also considered as one possible alternative for fast computation.

PhD. group. Photo: Rune Rolvsjord, NORCE

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AI-based multi-modal interpretation of logs for ahead-of-bit probabilistic ROP prediction. Geosteering and Formation Evaluation Workshop by NORCE and NFES; 2022-11-01 - 2022-11-02

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On Transitions Functions Model for Decision-Making in Offshore Operations. 2022 IEEE 17th International Conference on Control & Automation (ICCA); 2022-06-27 - 2022-06-30

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MEDIA

Rassenfoss, Stephen; Alyaev, Sergey.
A Study Suggests Geosteers Often Miss the Target. https://jpt.spe.org 2022-12-01

Personnel

Key researchers	Institution	Research area
Sergey Alyaev	NORCE	Geostreering
Adrian Ambrus	NORCE	Drilling
Ole Morten Aamo	NTNU	Controls
Ulf Jakob Aarsnes	NORCE	Drilling
Reidar Bratvold	UiS	Decision Analysis
Liv Almås Carlsen	NORCE	Drilling
Eric Cayeux	NORCE	Drilling
Benoit Daireaux	NORCE	Drilling
Erik Wolden Dvergsnes	NORCE	Drilling
Robert Ewald	NORCE	Drilling
Kristian Fossum	NORCE	Reservoir Engineering
Helga Gjeraldstveit	NORCE	Drilling
Jan Einar Gravdal	NORCE	Drilling
Andrew Holsaeter	NORCE	Drilling
Morten Jacobsen	UiB	Reservoir Geophysics
Nazanin Jahani	NORCE	Geosteering
Rodica Mihai	NORCE	Drilling
Sonja Moi	NORCE	Drilling
Gilles Pelfrene	NORCE	Drilling
Dan Sui	UiS	Control System
Erich Christian Suter	NORCE	Geosteering
Jan Tveranger	NORCE	Geology
Erlend H. Vefring	NORCE	Geosteering
Tomasz Wiktorski	UiS	Data Science

PhD students with financial support form the Centre budget

Name	*Nationality*	*Period*	*Sex M/F*	*Topic*
Ressi Bonti Muhammad	Indonesian	2021-2024	M	Sequential decision analysis in drilling and geosteering
Luis Alberto Saavedra Jerez	Bolivian	2021-2024	M	Impact of the expected measurement quality and uncertainty while working on the engineering of a well
Felix James Pacis	Filipino	2021-2024	M	Online / Offline Deep learning models
Pauline Nüsse	German	2021-2024	F	Automatic control of vibration-damping sleeves for drill strings
Durra Handri Saputera	Indonesian	2022-2025	M	Borehole electromagnetic modeling and inversion
Marios Gkionis	Greek	2022-2025	M	Extremum seeking control using ideas from reinforcement learning

Master degrees

Name	*Sex M/F*	*Topic*
Alisher Khodajev	M	Modelling of borehole electromagnetic induction logging data in anisotropic rock formations
Alina Shashel	F	Uncertainty analysis of Supervised machine learning predictions applied to Lithology classification
Muhammad Usama	M	Application of Deep Reinforcement Learning in Automated Managed Pressure Drilling
Emre Baris Gocmen	M	Trajectory control via reinforcement learning with RSS model
MD Fazlul Haque	M	Path design and optimization with obstacle avoidance via reinforcement learning
Ali Tahir	M	Impact of data preprocessing techniques on Machine Learning models

Statement of accounts

(All figures in 1000 NOK)

Funding			
	Amount	**In-kind**	**Sum**
The Research Council	10,491		10,491
The Host Institution (NORCE Energy)		1 000	1 000
Research Partners			
Universitetet i Stavanger, UiS			
Universitetet i Bergen, UiB			
Norges Teknisk-Naturvitenskapelige uni.		599	599
Enterprise partners			
Operators	10,000	1,249	11,249
Vendors		33	33
Public Partners			
Sum	**20,491**	**2,881**	**23,372**
Costs			-
The Host Institution (NORCE Energy)	16,129		16,129
Research Partners	5,362	599	5,961
Enterprise partners		1,282	1,282
Sum			**23,372**

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