Instrumentation and data management/analyses for Measurement While Drilling (MWD) technology:

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What is Measurement While Drilling (MWD):

AASHTO definition:
Near-continuous real-time operational and ground-response measurements from instrumented drilling equipment without interfering with the drilling process.

Real-time monitoring of the measured drilling parameters and compound drilling parameters may be used to aid drilling operations and efficiency, and to identify changes in subsurface conditions and material characteristics.

Drilling Parameters:

According to Bingham (1964), there are more than 26 parameters that could influence the drilling process

Some of these parameters include:

- ✓ **Type of drilling operation**
- ✓ **Drill bit type and configuration** ***(configuration of teeth and skewness of the cones)***
- ✓ **Drill bit Toothwear**
- ✓ **Length of drill rods (drilling depth) and lithography of the site**
- ✓ **Drilling inclination (deviation from vertical) during the drilling**
- ✓ **Mast vibration**
- ✓ **……**

Required Drilling Parameters (AASHTO symbols):

- Penetration Rate (u)
- Down Pressure or Crowd (F)
- Rotation Speed (N)
- Torque (T)
- Diameter

Quality Class 1 (Rotary Drilling):

- Fluid Injection Pressure (P)
- Fluid Injection Volumetric Flow Rate (Q_I)

Additional useful parameters:

- Fluid Return Volumetric Flow Rate (Q_R)
- Injected Fluid Density (ρ)
- Mast Vibration (accelerometer) (G)
- …….

Example data from Montana DOT

The ultimate goal (this project): information about Substrata (subsurface conditions and material characteristics)

- Determine changes in subsurface material characteristics and conditions
- Determine boulders, voids, faults, and fracture zones
- Undrained and Drained Shear Strength of soils
- Standard Penetration Test (SPT)-N value
- UCS of rocks
- Rock Quality Designation (RQD)
- ……

The ultimate goal (this project): information about Substrata:

Traditional method- Compound Parameters

Specific Energy (E_s)

$$E_s = \frac{F}{A} + \frac{2\pi NT}{Au}$$

- Penetration rate (u)
- Rotation speed (N)
- Down pressure (F)
- Torque (T)
- Surface area of the drilling hole (A)

Teale R. The concept of specific energy in rock drilling. Int J Rock Mech Min Sci. 1965 Mar 1;2(1):57–73

The ultimate goal (this project): information about Substrata:

Traditional method- Compound Parameters

- Penetration rate (u)
- Rotation speed (N)
- Down pressure (F)
- Torque (T)
- Diameter of the drilling hole (d)

Drillability, D_s

$$D_s = \frac{64NT^2}{Fud^3}$$

Karasawa H, Ohno T, Kosugi M, Rowley JC. Methods to estimate the rock strength and tooth wear while drilling with roller-bits - Part 1: Milled-tooth bits. J Energy Resour Technol Trans ASME. 2002 Sep 1;124(3):125–32

The ultimate goal (this project): information about Substrata:

Traditional method- Compound Parameters

Normalized Energy (E_N)

$$E_N = \frac{Fu + 2\pi NT + u_p E_p}{u}$$

Normalized energy (E_N) correlates very well with the number of blows obtained by the SPT

- **Penetration rate (u)**
- **Rotation speed (N)**
- **Down pressure (F)**
- **Torque (T)**
- **Surface area of the drilling hole (A)**

For rotary percussion drill

- **Percussion energy (Ep)**
- **Percussion rate (u_p)**

Nishi K, Suzuki Y, Sasao H. Estimation of soil resistance using rotary percussion drill. In: "Proceedings of the 1st Int Conference on Site Characterization, P K Robertson and P W Mayne, eds, Vol 1, AA Balkema, Rotterdam, Netherlands. 1998. p. 393–398

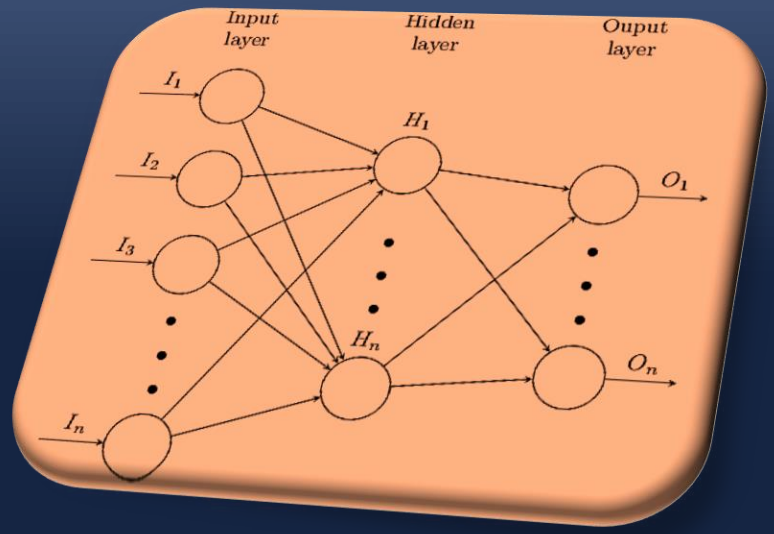
……Other correlations cited in AASHTO MWD Standard (draft)

The ultimate goal (this project): information about Substrata:
Data-Driven (Machine Learning) methods

Long-Term Goal: Develop a universal model

Take advantage of the flexibility of ML to incorporate additional data that cannot be included in traditional equations:

- Type of material (e.g., soft rock, hard rock, intermediate rock, gravel, sand, fine soil, ….)
- Type of drill rigs and tools
- Tooth Wear
- Mast vibration
- Fluid Injection Pressure (P)
- Fluid Injection Volumetric Flow Rate (QI)
- ……



Measurement While Drilling (MWD) system:

- **Sensors:** ***convert physical parameters (drilling parameters) to electrical signals.***
- **Data logger [Data acquisition (DAQ) hardware]:** ***recording the signal, signal conditioning, and displaying the drilling parameters***
- **Software:** ***receive/convert the data and control the data acquisition process***

Commercially available MWD systems

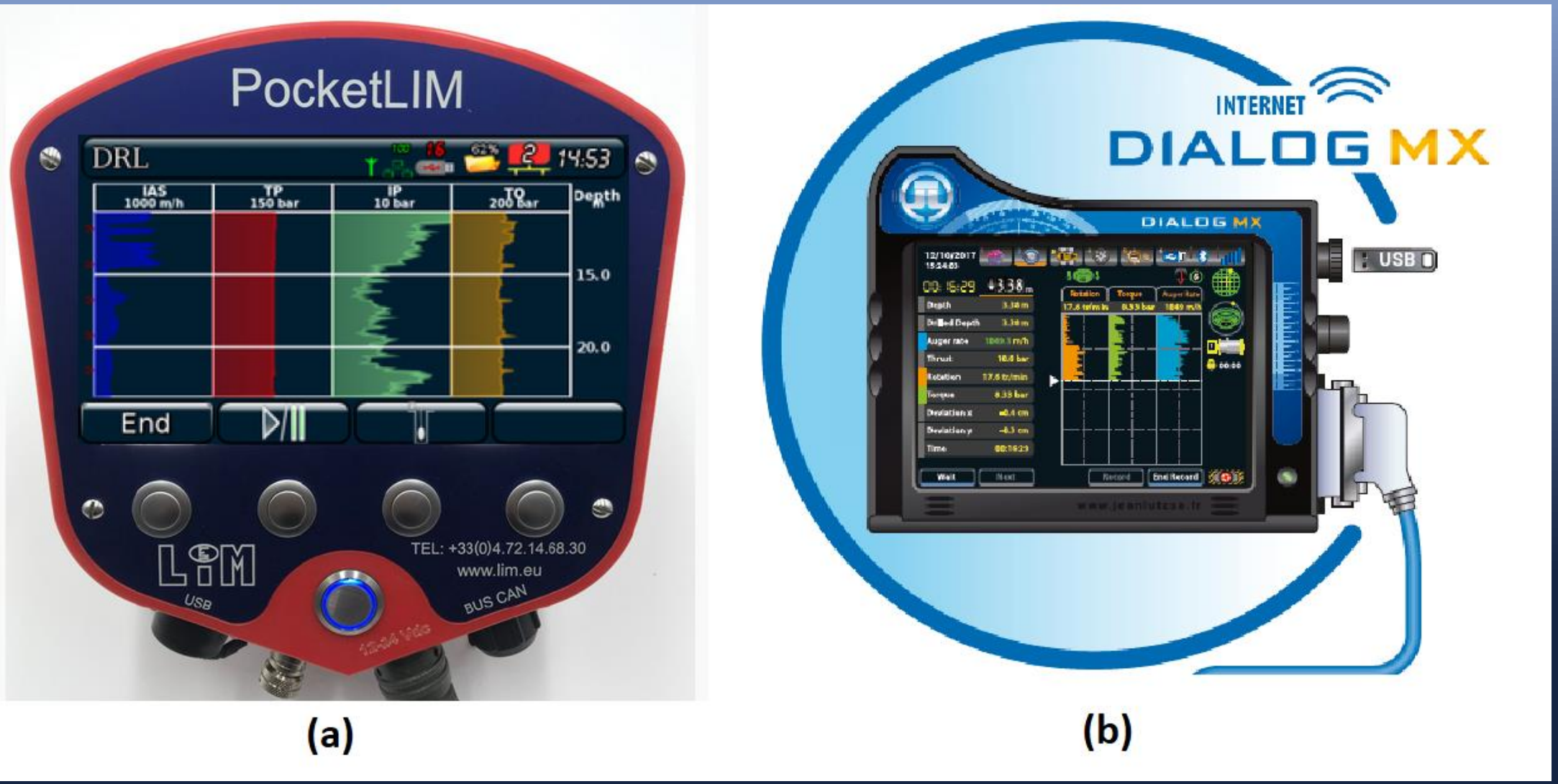
Choosing criteria

Questions:

- Can we get the data both with Time-stamp and depth?
- Is it possible to add more sensors (e.g., MWD ONE, Accelerometers, …..)?
- Is it possible to get the data in DIGGS format?
- Are they capable of recording the data with a sampling frequency of 100 Hz (which is required for AASHTO's quality class 1)?
- Are they equipped with a Global Positioning System (GPS) for recording the location of drilled holes?

Choosing criteria	JeanLutz	LiM
Data vs. Time-stamp and depth	✓	✓
Possibility of adding more sensors	✓	✓
Data in DIGGS format	✗	✓
Sampling frequency of 100 Hz	✓	✓
GPS	✓	✓

Choosing criteria



Thank You