TBM Applications III Innovations in TBM Tunneling



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Shaping a **Better Life**

Agenda

Innovation in TBM Tunneling from a contractors view:

- 1. Robotic in tunnel
- 2. Data analysis

Bouygues Company



Today's & Future challenges in tunneling



TBM Applications III - Innovations in TBM Tunneling

ROBOTICS



ROBOTICS...for TBM cutterhead inspection & maintenance

Jet-snake:

- ✓ Remote control Cutterhead inspection arm
- ✓ able to access to excavation chamber to clean and inspect the TBM cutterhead
- ✓ Work under hyperbaric conditions (7 bars)



ROBOTICS...for TBM cutterhead inspection & maintenance

TELEMACH: A robot to change cutter discs

- ✓ Multi purpose arm able to access to excavation chamber to clean and change cutter disc
- \checkmark Work under hyperbaric conditions (7 bars)
- ✓ Remote control from operator control room (atmospheric condition) using cameras





ROBOTICS...for TBM cutterhead inspection & maintenance

TELEMACH: A robot to change cutter discs

- ✓ With Telemach Replacement of cutter disc involves:
 - ✓ <u>No</u> Intervention of workers in hyperbaric atmosphere
 - ✓ No Working in confined space
 - ✓ No Handling of heavy duty elements





ROBOTICS...for Ring Erection

ATLAS: full automatic ring building system

- 1. Ergonomy & safety
 - Limited intervention of operators in the erector zone
 - Difficult access in the lower tunnel part
 - •
- 2. Productivity
 - Repetability for ring erection duration
 - From 3 min to more than 7min per segment
 - Current target 3.30 min per segment actual output 4.30 min per segment 34 min for a complete 8 segment ring
- 3. Quality
 - Tolerances (mm)
 - Ring positionning versus tail skin position
 - Ring reports





ROBOTICS...for Ring Erection

ATLAS: full automatic ring building system

In house BY development with external specialists and University Currently under deployment on Grand Paris Project







ROBOTICS...for Ring Erection

ATLAS: full automatic ring building system



Segment installation EOLE Project (Paris 2019)

Real speed x4 - real duration \approx 4 min

ROBOTICS...for Drilling & anchors installation

ROBY 850: A robot to change cutter discs

- 1. Ergonomy & safety
 - Access at height not required
 - Equipped with a dust sucking device
- 2. Productivity
 - Repetability
 - 4 min for drilling + anchor installation
- 3. Quality
 - Tolerances (mm)







ROBOTICS...for Drilling & anchors installation



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DATA ANALYSIS





SENSORS

MOBYDIC: A new sensor

By monitoring several parameters of the cutterdisks (rotation speed, temperature, etc.), Mobydic allows for:

- Real time geological face mapping
- More accurate calculation of the excavated quantities
- Cutter disc wear status







Computation

o Existant

Tunnel Lab 2018

o Tunnel Lab 2019

Global Solution





An essential pair



1 DataScientist

1 Business expert

Stages of a Data Science Project



Resc Outs from the Dole Late Or event selects in the relevent variables among the huge Doto Set mer dole analable Or An append selects in the relevent variables among the huge Or one set one dole analable Or And the appendix of the intervent variables among the huge Or And the appendix of the intervent variables among the huge Or And the appendix of the intervent variables Or And the appendix of the intervent variables So is created the Working Data Set which becomes the input of the iteration of Data Science

DATA ANALYSIS



MODELLING



3 to 6 months



⁽³⁾ A Data Scientist gets the data set, cleans it, and applies a statistical algorithm of variables combination



AX1 vs AX2 vs AX3

(3) A Data Scientist gets the data set, cleans it, and applies a statistical algorithm of variables combination

⁽⁴⁾ An Expert gives an business interpretation of the variables combinations defined for each axis



AX1 vs AX2 vs AX3

(3) A Data Scientist gets the data set, cleans it, and applies a statistical algorithm of variables combination

An Expert gives an business interpretation of the variables combinations defined for each axis

⁽⁵⁾ A Data Scientist divides automatically the data set. The group of elements is defined with the business team



- (3) A Data Scientist gets the data set, cleans it, and applies a statistical algorithm of variables combination
- (4) An Expert gives an business interpretation of the variables combinations defined for each axis
- (5) A Data Scientist divides automatically the data set. The group of elements is defined with the business team
- ⁶ An Expert and a Data Scientist interpret each group of elements



- (3) A Data Scientist gets the data set, cleans it, and applies a statistical algorithm of variables combination
- 4 An Expert gives an business interpretation of the variables combinations defined for each axis
- (5) A Data Scientist divides automatically the data set. The group of elements is defined with the business team
- 6 An Expert and a Data Scientist interpret each group of elements
- An Expert interprets the position of each group to the business axis



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- 4 An Expert gives an business interpretation of the variables combinations defined for each axis
- (5) A Data Scientist divides automatically the data set. The group of elements is defined with the business team
- 6 An Expert and a Data Scientist interpret each group of elements
- O An Expert interprets the position of each group to the business axis
- Expert and Data Scientist check the classification consistency with another data source



③ A Data Scientist selects a compatible modeling type, optimizes the model parameters by learning on a part of the data set and tests its performance on the remaining data, unknown for the model

94%

Correct prediction score of classes

Wrong prediction score of classes

The Ground Machine Interaction Indicator is a machine learning algorithm trained on past slurry sites.

21.95 It computes stream an indicator based on a set of technical data from the TBM.

This indicator gives a difficulty class to dig the ring.

The + Machine Learning Algorithm New production indicator Streaming Enhances past experiences

Patent Pending

Tuen Mun Chek Lap Kok Hong Kong TBM 17,6m diam

Thank you for your attention !

