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Data analysis in geotechnics – an approach to the construction of an urban tunnel

Analyse de données en géotechnique - une approche dans la construction d'un tunnel urbain

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ABSTRACT: In contexts where empirical methods support decision-making, the need for organized information, often in a 'Just in Time' manner, is crucial. In such situations, machine learning (ML) and artificial intelligence (AI) based methods can play a significant role in offering meaningful solutions. Data must fulfil predefined criteria and be stored in structured databases. Quality of information and its organization are essential factors for predictive and decision-making algorithms. This paper will introduce essential database criteria and provide an example of data analysis for a case study to offer effective decision-making support for an underground construction project in an urban environment. In NATM (New Austrian Tunnelling Method) works, there is a heavy reliance on continuous monitoring and observation. Particularly in linear excavations, work cycles follow each other rapidly, often operating 24/7. The constant decision-making required for the progress of each daily cycle demands continually updated information that is readily available and presented in a clear and precise format for quick and rigorous interpretation.

RÉSUMÉ: Dans les contextes où les méthodes empiriques soutiennent la prise de décision, le besoin d'informations organisées, souvent en mode 'juste à temps', est crucial. Dans de telles situations, les méthodes basées sur l'apprentissage automatique (ML) et l'intelligence artificielle (IA) peuvent jouer un rôle significatif en offrant des solutions significatives. Les données doivent respecter des critères prédéfinis et être stockées dans des bases de données structurées. La qualité de l'information et son organisation sont des facteurs essentiels pour les algorithmes de prévision et de prise de décision. Cette communication introduira des critères essentiels pour les bases de données et fournira des exemples d'études de cas d'analyse de données afin d'offrir un soutien efficace à la prise de décision pour un projet de construction souterraine en milieu urbain. Les travaux réalisés selon NATM (New Austrian Tunneling Method) reposent largement sur la surveillance et l'observation continues. Particulièrement dans les excavations linéaires, les cycles de travail se succèdent rapidement, souvent en fonctionnement 24/7. La prise de décision constante nécessaire à l'avancement de chaque cycle quotidien exige des informations continuellement mises à jour, disponibles rapidement et présentées dans un format clair et précis pour une interprétation rapide et rigoureuse.

Keywords: Business intelligence; advanced data analysis; machine learning; Python; NATM; tunnels.

1 INTRODUCTION

The organization of data enables the search for predictive models, supports decision-making through algorithms, which can be established by AI, with the ultimate goal of automating processes.

Relational database technology has been adopted since the late 1970s (Vaisman and Zimániy, 2017). However, despite not being a new tool, some industries have not fully embraced the advantages it offers. Organized and structured information simplifies data analysis process.

Construction sector data management will improve with software like Building Information Modelling (BIM).

Efforts need to be made to evolve Big Data and AI strategies to achieve predictive algorithms.

This paper deals with underground excavation information from Circular Line construction contract of Metro do Porto (MdP) in progress, and some

hypothesis to data organization, management and analysis. It is an approach by construction site engineers, looking for decision-making tools.

2 BACKGROUND

Briefly, significant research and applications exist related specifically to data analysis through advanced algorithms to infer characteristics, predict trends, support decision making, etc., related to geotechnics in general (Gomes Correia et al., 2023; Gomes Correia, et al., 2020).

The interest of the subject it is clearly shown among academics and professional bodies like Federation of International Geo-engineering Societies (FedIGS), through the organization of regular event International Conference in Information Technology in Geo – Engineering (ICITG), launched by Joint Technical Committee 2 (JTC2) dedicated to Representation of Geo-engineering Data in Electronic Format (Gomes Correia et al, 2020). Also, TC309–Machine Learning and Big Data in ISSMGE, represents the same interest, in: 1) benchmark datasets, 2) Big Data acquisition, 3) site investigations and geo-materials behaviour; 4) Design; 5) Construction and maintenance; 6) industry interaction, standards and guidelines, points out to ML supported in geo-data, learning and making previsions, supported in AI algorithms (Zili Li et al, 2023). More recently, The International Society for Intelligent Construction (ISIC) is also working in the same line to provide source of knowledge and information on intelligent construction technologies for public agencies, contractors, consultants, academia, etc. (Gomes Correia, et al., 2020).

When I&D turns to concepts like *distributed ledger technologies* (DLT) or *blockchain* and *data lakes* (e.g. Mourão, 2022), or when internet of things (IoT) bring us the idea to access Data directly from devices, equipment's and machines, it is difficult to accept that old relational data bases or data base management systems are still not fully implemented.

3 INFORMATION TECHNOLOGY IN MdP CIRCULAR LINE CONSTRUCTION CONTRACT

Construction sector has already implemented commercial software platforms to communicate and manage documentation, between different stakeholders, in many cases as a contractual obligation established by the owner and NP EN ISO9001, Quality System Management System, documents normalization and control, related to the operationalization process and quality.

More recently, BIM, promise to bring the expected digital revolution to the sector, together with proper and long expected Data management. However, this technology it is not fully implemented in Portugal, regulation by "Portaria n.º 255/2023", recognizes that BIM importance justifies its use in public works project design. MdP Circular Line it is supported in BIM as a constructor contractual obligation. Implemented under its full capacity it enables daily analysis of solutions compatibility.

In construction operations, processes are established by Quality systems of Contractor, and approved by Supervisor. This includes executing, measuring and monitoring, safety and health procedures, like normalizes documents in use. The information collected along the way, it is frequently compiled in datasheets obeying to established formats and organized in a set of digital directories like a hierarchical db. This manual compilation of information it is done, independently, by different stakeholders (Contractor, Supervisor and Owner).

The overall system works and data it is available and accessible, but some work it is redundant (different player's repeat data compilation with same data), in a manual, arduous and repetitive labour. This system assures access to information (Python routines have already successfully tested), but it is not optimized, neither in data management, nor in the quality data analysis that enables.

4 PROCESSES WORKFLOW, INFORMATION AND RELATIONAL DATABASE

Evaluate processes workflow it is a need to plan activities during construction. Through an entity relationship diagram, can be identified the information produced and necessary along the process (Figure 1). Include in such diagram, all the dimensions (quality, environment, health and safety,…) of a construction contract in public works, can be a complex and extensive task. Along the process, routines supported in different code languages can be used, like SQL and Python.

Frequently, digital information acquired automatically it is transformed in pdf files or even paper support data, and loaded by different stakeholders, in a redundant, monotonous, laborious and joyless task. Sometimes, to approach specific questions, some organizations, reload information to a new shape or format, wasting time and resources.

When the process it is well known and all the variables are identified, the structure of a relational database can arise. The model of a data base, through

an entity-relation diagram can establish the architecture constructed with SQL code. At that stage, data loading may begin. This phase, however unavoidable, at least to some extent, can be minimized through: 1) automatic data acquisition; 2) shared database (Contractor, Supervisor and Owner).

5 RAW DATA TO A DATABASE

The ideal or traditional formula for planning and architecting an appropriate database for a specific project is not always achievable, be it due to limited project resources or lack of long-term perspective in project, life-cycle, or asset management.

When there is not a proper database, but instead exists dispersed data, more or less organized, but without pre-established formats or key links, it is still possible to organize the information to allow data analysis, through successive stages: extract, transform and modelling data. Lower quality initial data, enhance data edition challenge.

Considering that data sources are adequate, exists commercial software to enable all the phases of the process: 1) extract; 2) transform; 3) modelling; 4) calculations; 5) visualization; 6) publishing. In different moments of the process, AI algorithms enables simplification and automatic decisions.

Power BI, supporting DAX and M languages, enables to extract and transform data, as a interactive business intelligence and data visualization tool with visually appealing reports, dashboards, data insights, and a user-friendly interface.

During construction works on the Circular Line of MdP, attempts were made to data analysis: 1) Python code enables data analysis relative to excavation with explosives, stored it in an external server, and presenting the results graphically and periodically reports; 2) data is stored in an external server and fed into a business intelligence report using Power BI.

As an example, Figure 2 shows a detail of a Power BI report related to the vibrations monitoring due to the use of explosives in an area classified by UNESCO, adjacent to the iconic Torre dos Clérigos, where this project imposed a Vmax<2,5mm/s, strincter than the regulations set by standard (NP2074, 2015), that establishes 3mm/s as the maximum value for sensitive buildings.

6 FINAL REMARKS

NATM relies on continuous monitoring and observation. Together with settlements, groundwater levels, convergences data, all the information on design and operations represents a large amount of data, which is not always easy to navigate through and interpret in order to support decisions just in time (JIT), if it is not properly stored and managed.

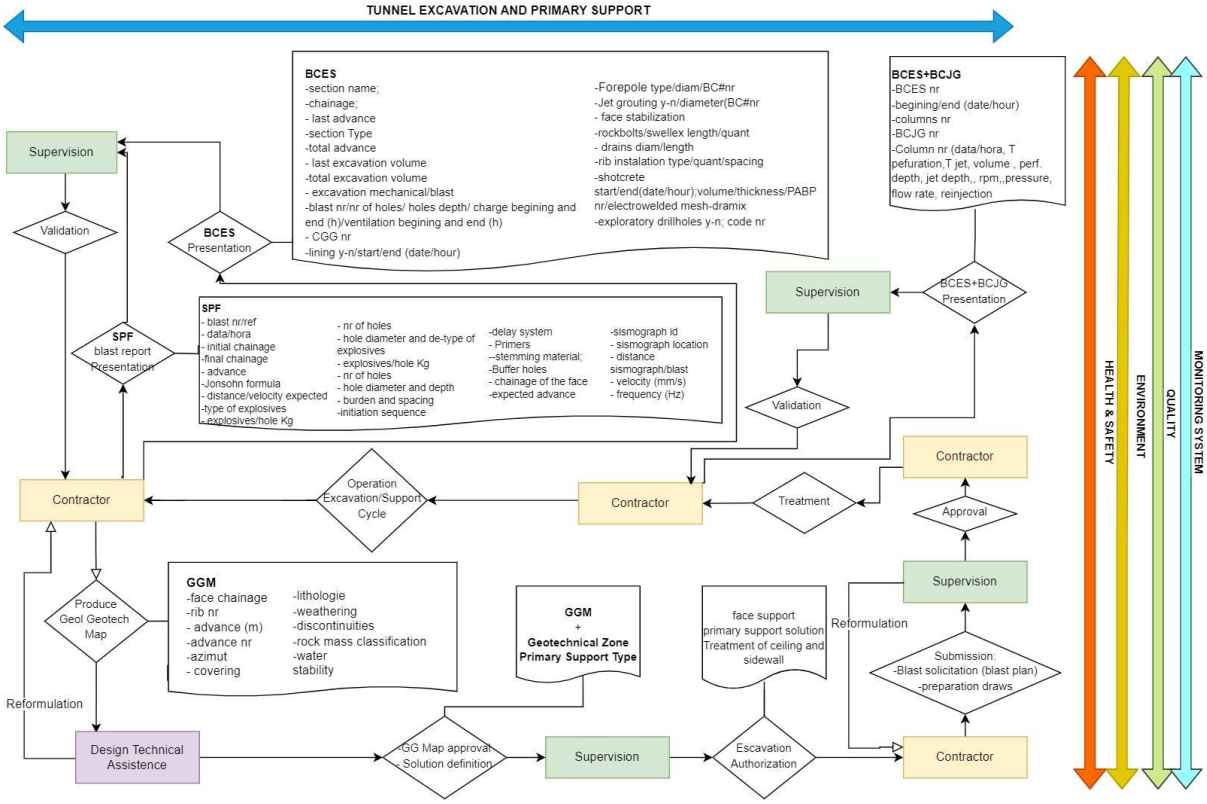

Figure 1. Tunnel excavation and primary supports processes workflow entity-relation diagram.

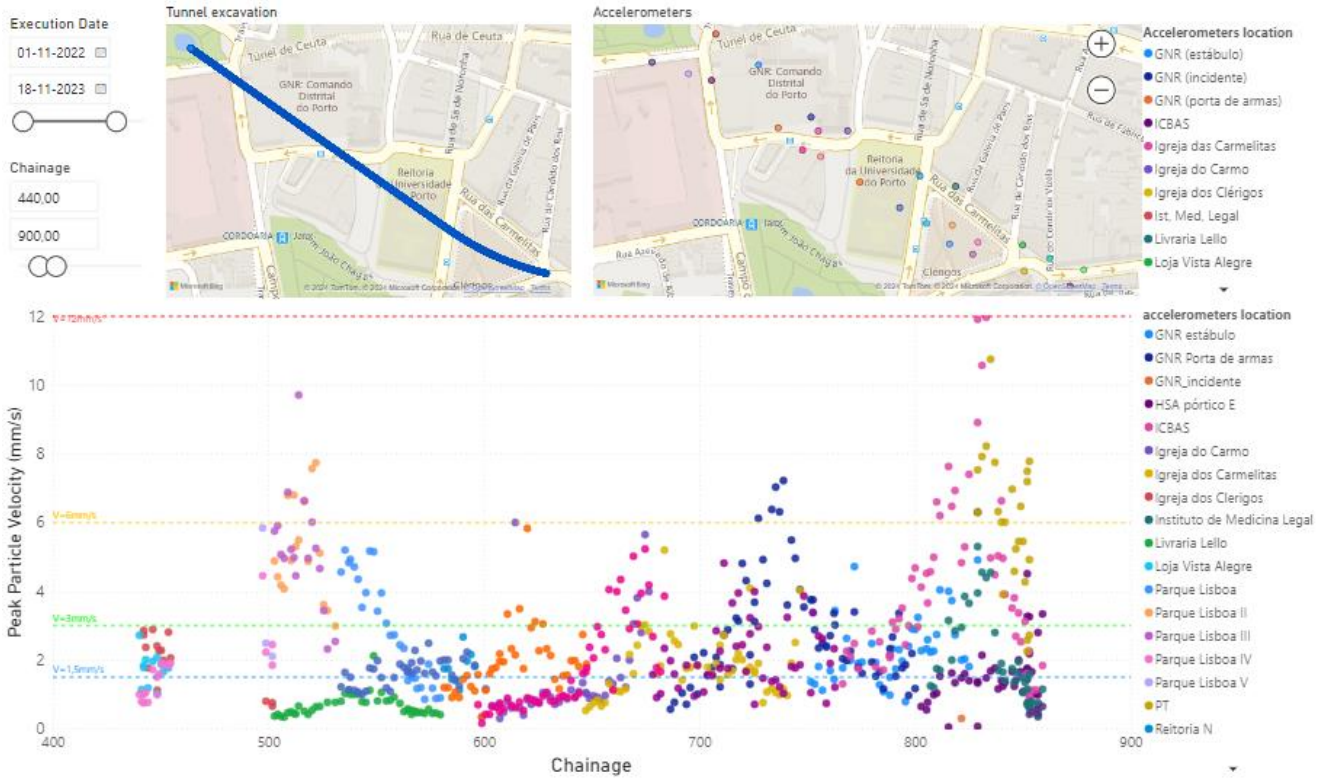

Figure 2. Blasting monitoring results data analysis.

In such environment, an attempt it being made to define a conceptual SQL database and to carry out data analyses on the real and existent hierarquical folders database, with Python code and Power BI.

Data and its management are critical for NATM construction operations, but must also remain available for the life-cycle and asset management.

This theme is in progress, as it addresses a subject still under study and which we hope to develop further in the future. Initially, this will involve data acquisition and storage methods, followed by the implementation of data analysis. At a more ambitious level, it encompasses the establishment of automated data analysis routines and decision support, involving artificial intelligence and machine learning algorithms.

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