Animation and visualisation of rock mass behaviour types

Evaluation of various programmes with subsequent application using a practical example

Malte Baumscheiper, BSc
Advisor: Univ. Prof. Dipl.-Ing. Dr. Matthias Flora
Unit of Construction Management and Tunnelling
University of Innsbruck
ibt@uibk.ac.at | *www.uibk.ac.at/ibt*

ABSTRACT: Digitalisation in tunnel construction, in particular through tunnel information modelling, enables optimisation in planning and execution. This work compares different software solutions for the animation and visualisation of rock mass behaviour types and evaluates their suitability. Despite limitations in the animation, especially in the representation of transitions between rock behaviour types, the analysis shows potential for future developments in mechanised tunnelling. Future research should focus on the integration of logistics and effort values as well as co-operation with digital twins in order to further increase efficiency in planning processes. Rapid progress in 3D visualisation is necessary to catch up with other construction sectors in tunnelling.

Complete work: *www.uibk.ac.at/ibt/lehre/abgeschlossene-masterarbeiten/*

KEYWORDS: TIM, BIM, Rock behaviour types, Animation, Unity

1 INTRODUCTION

Construction projects are increasingly being managed digitally through Building Information Modelling (BIM) and Tunnel Information Modelling (TIM) to minimise design errors, reduce costs and mitigate risks. TIM enables better decision-making through the integration of various data sources and supports the entire life cycle of tunnelling projects. Artificial intelligence and autonomous systems optimise the construction process, while visualisations such as VR facilitate understanding.

2 THEORY

Increasing digitalisation in tunnel construction is leading to greater use of modern methods such as Building Information Modelling (BIM), which is used specifically as Tunnel Information Modelling (TIM) in underground construction. TIM enables comprehensive modelling and management of project information over the entire life cycle of a structure. The ‘digital twin’ plays a central role here: it supports the planning, construction and maintenance of tunnels in real time through bidirectional data exchange with sensors and IoT technologies.

Visualisation potential lies in particular in the precise modelling of subsoil and geology, which enables improved planning, risk assessment and decision-making. Digital models also facilitate the coordination and cooperation of all project participants and offer opportunities for virtual and augmented reality applications to better visualise geotechnical conditions. However, the standardisation of data formats and the acceptance of new technologies in the industry remain challenges[1]

Visualisations and the use of VR (virtual reality) as well as the integration of BIM have already been classified as having great potential in building construction. [2] This step must now also be taken in tunnelling.

3 SOFTWARE COMPARISON ANALYSIS

Several software programmes are compared on the basis of five main categories: User interface and user experience, data import, animation capabilities, movement along paths and collision, and data export. The programmes analysed include 3ds Max, Cinema 4D, Blender, TwinMotion, Lumion and Unity. Each software is characterised by different strengths, with 3ds Max and Cinema 4D standing out in particular due to their professional features and extensive training options. Blender impresses with its open source nature and flexibility, while TwinMotion and Lumion focus on user-friendly real-time visualisation.

In the field of animation, 3ds Max and Cinema 4D offer comprehensive tools, while Blender impresses with its modular structure and customisability. TwinMotion and Lumion, on the other hand, have limited animation and collision detection functions. Unity offers a flexible script-based architecture that makes it possible to create and reuse animations independently of projects.

In conclusion, Unity is selected as the most suitable program for the visualisation of an example project due to its flexible, reusable animations supported by C# and database integration.

4 ANIMATION EINES BEISPIELS

The project selected is Baulos H41 of the Brenner Base Tunnel. This construction lot extends from Innsbruck to the village of Pfons, approx. 15 km south of Innsbruck. The ‘Unity’ programme was used after prior evaluation. There are 4 different GVTs in the construction lot. These were characterised in the geotechnical report. They are defined in the following table in accordance to ÖNORM 2203-1. [3]

Rock behaviour types	Description
GVT 2	Großvolumige gefüge- und schwerkraftbedingte Ausbrüche, vereinzelt lokales Überschreiten der Scherfestigkeit an Trennflächen (Large-volume structural and gravity-induced break-outs, occasional localised exceeding of the shear strength at interfaces)
GVT 3	Spannungsbedingte Neubrüche bzw. Plastifizierung des Gebirges in Hohlraumnähe, ev. in Kombination mit gefügebedingten Ausbrüchen (Stress-induced new fractures or plasticisation of the rock near cavities, possibly in combination with structure-induced breakouts)

GVT 4	Spannungsbedingte tiefreichende Neubrüche bzw. Plastifizierung im Gebirge mit großen Deformationen (Stress-induced deep new fractures or plastification in the rock mass with large deformations)
GVT 7	Großvolumige Ausbrüche überwiegend im Firstbereich mit progressiven Scherversagen (Large-volume breakouts predominantly in the ridge area with progressive shear failure)

Tab. 4-1: Superordinate categories of GVTs [4]

4.1 MODELLIERUNG

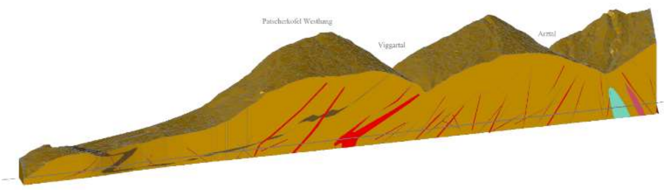

Abb. 4-1: Visualisation of the geological model

The ground surface is modelled with CIVIL 3D using laser scan data and extruded in 3D. Geological sections are created using cross section and tender documents. The model is then transferred to the Unity programme, using the FBX format for export. Different rock behaviour types (GVTs) are visualised in the model and displayed in colour. The tunnel cross-sections are modelled along the tunnel axis at 1-metre intervals, whereby the GVTs and their percentage distribution are integrated

The individual objects are linked together in 'Unity'. The tunnelling machine is loaded into the project as an additional body. This has the function of visualising the movement within the tunnel corridor and for collision checking.

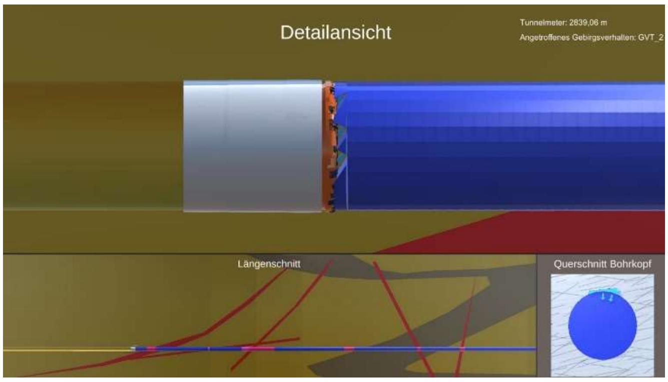

Abb. 4-2: Visualisation of GVT 2 in Unity

4.2 ADDED VALUE AND LIMITATIONS OF THE ANIMATION

The animation of the rock mass behaviour and the movement of the tunnel boring machine (TBM) along the tunnel axis can be adapted for other tunnel projects. The TBM is scalable and only visually relevant. The added value of the animation lies in the planning and execution phase, in that expenditure values are visualised, forecast uncertainties are better represented and logistics are optimised. Limitations include the lack of dynamic reaction of the rock mass and the high cost of particle effects in future projects.

5 CONCLUSION

The aim of this master's thesis was to compare different software solutions for the visualisation and animation of rock mass behaviour types in tunnel information modelling. Criteria such as data import, export and animation options were analysed. The 'Unity' programme was selected due to its modularity and programmability and was used for the animation of construction lot H41 of the Brenner Base Tunnel. The work shows the potential of animations, but points out limitations such as imprecise transitions between rock behaviour. This work serves as a basis for future developments in the field of visualisation in tunnel construction.

6 OUTLOOK

This thesis examines six programmes for visualisation and animation in tunnel construction. The animation was only implemented at a basic level, with potential for the integration of further rock behaviour types and effects. Future developments should include effort values and logistics to improve usability via digital twin and database. Extensions to conventional tunnelling and deeper studies could facilitate the planning processes.

7 QUELLEN

[1] DAUB-Arbeitskreis, Hg., *Modellanforderungen - Teil 3: Baugrundmodell*, 2022. [Online]. Verfügbar unter: https://www.daub-ita.de/filead-min/documents/daub/gtcrec5/2022-08_DAUB_BIT_Model-lanforderungen_T3_Baugrundmodell_Rec_DE.pdf

[2] A. David, E. Joy, S. Kumar und S. J. Bezaleel, "Integrating Virtual Reality with 3D Modeling for Interactive Architectural Visualization and Photorealistic Simulation: A Direction for Future Smart Construction Design Using a Game Engine" in *Lecture Notes in Networks and Systems Ser*, v.300, *Second International Conference on Image Processing and Capsule Networks: Icipcn 2021*, J. I.-Z. Chen, Hg., Cham: Springer International Publishing AG, 2021, S. 180–192, doi: 10.1007/978-3-030-84760-9_17.

[3] Austrian Standards, Hg., *ÖNORM B 2203-1: Untertagebauarbeiten – Werkvertragsnorm*. Teil 1: Zyklischer Vortrieb, 2023. Aufl.

[4] Österreichische Gesellschaft für Geomechanik, *Richtlinie Geotechnische Planung von Untertagebauten Zyklischer und Kontinuierlicher Vortrieb: Gebirgscharakterisierung und Vorgangsweise zur nachvollziehbaren Festlegung von bautechnischen Maßnahmen während der Planung und Bauausführung*, 2023.