Technology Strategy Board
Driving Innovation

Knowledge Transfer Network

Industrial Mathematics

Don't get the bends

A UNIFIED DECOMPRESSION MODEL FOR DIVERS

VR Technology Ltd / University College London / University of Birmingham

The need

Breathing compressed air at depth causes an increasing amount of gas to dissolve into tissue. Upon resurfacing this gas comes out of solution and can cause problems leading to Decompression Sickness (DCS). The need is thus to manage the escape of gas from the body in such a way that the diver can exit the water safely.

VR Technology has identified the need for an improved decompression algorithm for recreational and commercial divers that can be used across a whole range of depths, particularly in the range 0-150m. Their Variable Gradient Model (VGM) is a first attempt at bridging this divide that also incorporates user customisability to allow for different risk tolerances.

The outcomes

The project enabled VR Technology to improve upon their existing VGM algorithm incorporating aspects of Bühlmann models with microbubble theories, essentially extending the range of depths over which their model can be used whilst maintaining substantial customisability for both the company and the user.

Furthermore, work on tissue models underline the complicated nature of decompression theory. This part of the project has enabled the company to feel confident with their current algorithms and given them a foundation on which to base future decompression models containing microbubble physics.

The project allowed the student to gain an understanding of the nature of decompression modelling in the human body. The skills gained by the student included tailoring mathematical concepts for commercial use and numerical methods such as finite difference solutions of diffusion equations employed in the tissue model. Involvement with the company enabled the student to interact with different departments particularly when explaining his ideas, in addition to appreciating the effort involved in running a medium sized company.

"The results and progress have exceeded our expectations. We will continue to keep working with the KTN and the members of the team to continue this project and start others."

Nick Bushell
VR Technology

Technical summary

Despite compressed air diving having been carried out for over a hundred years, decompression theory has advanced little in that time. For simplicity, the body is thought of as 16 compartments, each with its own gas dissolution half-time, and a decompression profile is calculated to maintain the partial pressure of gas within each compartment below a threshold that has been derived empirically. The coefficients used for decompression tables vary between different organisations for different depths.

According to Bühlmann in his 1983 book on *Decompression Sickness*, decompression is governed by so-called *b*-values, which need to vary smoothly throughout the range of depths. These values were modelled using a hyperbolic tangent function. Trial and error was then used to determine the coefficients that allow users to adjust how aggressive they want their dives to be. The old algorithm was used as a benchmark in the range 0-80m for which decompression tables are well documented.

In parallel, the company also wanted a method for validating their algorithms based on a more scientific approach to decompression modelling. It is hypothesised that microbubbles in the body, formed from gas coming out of solution, contribute to DCS. A tissue model containing stable nuclei from which microbubbles can grow was developed to calculate gas absorption and subsequent bubble dynamics. The aim was to monitor and limit microbubble size, in order to reduce the likelihood of DCS for a given decompression profile.

"The internship with VR Technology has allowed me to be part of the development of a new decompression algorithm that could positively impact the experience of divers all over the world. The valuable insights into the use of mathematics in industry and the skills acquired during the project will be useful in my PhD research and career."

Jean-Pierre O'Brien
University College London

"This internship has advanced our understanding of decompression sickness and has identified areas for future work and collaboration. It is a prime example of how mathematical modelling can be used to solve industrial problems."

David Leppinen
University of Birmingham

"This project has been an extremely useful and valuable exercise for Jean-Pierre. He has learnt a number of skills in applying novel mathematics to an industrially relevant problem and the project has provided some additional insight into his own PhD research on microbubble contrast agents."

Nick Ovenden
University College London

Project Details

Partners

VR Technology Ltd
University College London
University of Birmingham

Project investment

£12,000

Intern

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This project was part of the programme of industrial mathematics internships managed by the Knowledge Transfer Network (KTN) for Industrial Mathematics. The KTN works to exploit mathematics as an engine for innovation. It is supported by the Technology Strategy Board, in its role as the UK's national innovation agency, and the Engineering and Physical Sciences Research Council, in its role as the main UK government agency for funding research and training in engineering and the physical sciences.

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