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# Virtual reality in hydrography

## Immersive visualisation of the Arctic Clyde Inlet (Canada) using bathymetric and terrestrial data

*An article by MONA LÜTJENS, THOMAS P. KERSTEN, BORIS DORSCHEL and FELIX TSCHIRSCHWITZ*

Due to recent advances in hardware and software technologies, virtual reality (VR) is becoming ubiquitous, finding its use in more and more professional applications apart from the gaming industry. Up to now, VR could be successfully implemented for virtual surgery, virtual therapy, flight and vehicle simulations and cultural heritage. While geographical data sets are commonly projected in a top-down view onto a 2D surface, virtual reality could become a helpful tool to visualise terrain data in a more intuitive and immersive way. This study covers the methodology, advantages, limitations and practical usages of such visualisation tools for hydrographic applications.

virtual reality (VR) | digital elevation model (DEM) | game engine | multibeam echo sounder | bathymetric data

**Authors**

Mona Lütjens is a PhD student of Hydrography at HafenCity University Hamburg.

Thomas Kersten is Professor for Photogrammetry and Laser Scanning at HafenCity University Hamburg.

Dr. Boris Dorschel is Head of Bathymetry at Alfred Wegener Institute in Bremerhaven.

Felix Tschirschwitz works as a Research Assistant at HafenCity University Hamburg.

mona.luetjens@hcu-hamburg.de

## Introduction

Throughout time, visualisations of the earth's surface have not only been used for navigation purposes but also to better understand geospatial relationships. However, geospatial problems and questions are often 3D in nature, yet data has to be shown as a 2D surface like a map or on a 2D computer monitor. Reducing the dimensionality will force users to compensate the missing dimension creating cognitive challenges.

One method to depict terrain in three-dimensions is using virtual reality (VR). Opposed to virtual models displayed in 2D, the user is immersed in a computer-generated environment and becomes an actor rather than a spectator. Movements such as walking or head movements in real world are transferred to corresponding motions in the virtual environment allowing the user to immerse in the VR and decouple from reality.

This article shows the potential of VR in a case study for Clyde Inlet, a newly mapped Arctic fjord. In a VR application, Clyde Inlet is visualised above and below sea level.

## Area of investigation and implemented data sets

The area under investigation measures 160 km × 80 km and comprises the fjord system of Clyde Inlet on eastern Baffin Island, Nunavut, Canada. The elevation ranges from –847 m below sea level at the shelf edge to 1894 m at Baffin Island's interior plateau. Clyde Inlet is located in the Baffin Mountains which are part of the Arctic Cordillera mountain range – a north-eastern flank of the Canadian Arctic Archipelago. Clyde Inlet is a 120 km long fjord system that stretches from the Baffin Bay south-westwards towards Barnes Ice Cap and includes three major geographic features as illustrated in Fig. 1.

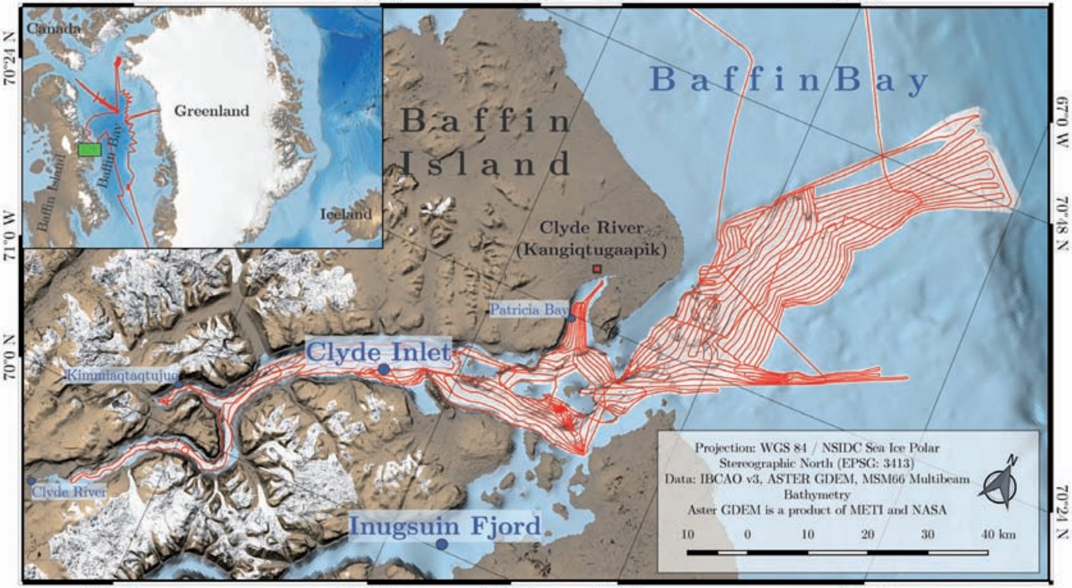

**Fig. 1:** Overview of Clyde Inlet showing track lines (red) of cruise MSM66

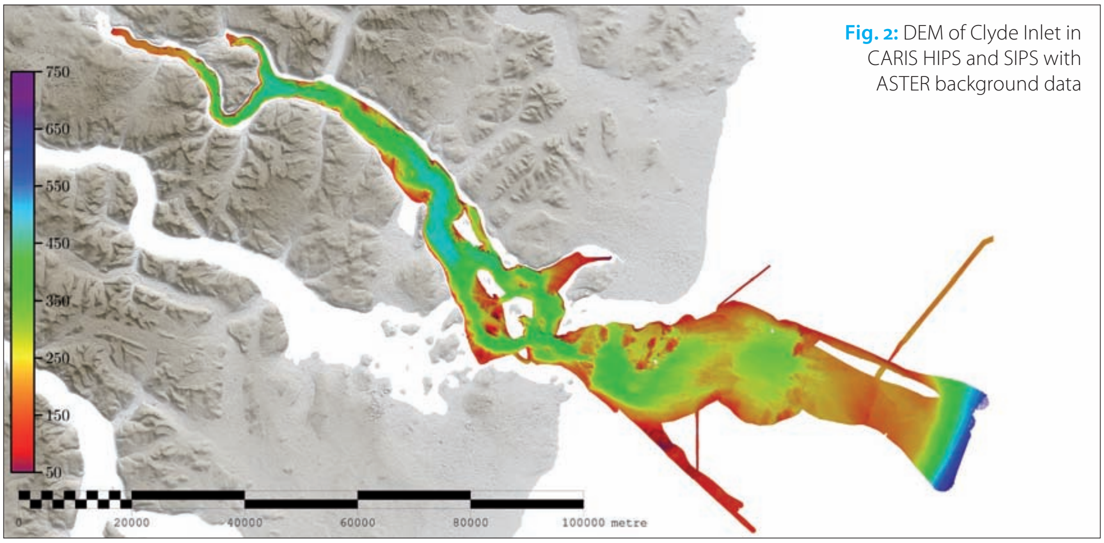

**Fig. 2:** DEM of Clyde Inlet in CARIS HIPS and SIPS with ASTER background data

In order to generate a coherent digital elevation model (DEM) of the entire terrain several data sets were implemented as listed in the following:

- Bathymetric data from the cruise MSM66 with 5 m resolution;
- Bathymetric data from IBCAO (International Bathymetric Chart of the Arctic Ocean) with 500 m resolution (Jakobsson et al. 2012);
- Terrestrial data from ArcticDEM with 2 m and 5 m resolution (Polar Geospatial Center & Regents of the University of Minnesota 2017);
- Terrestrial data from CanadianDEM with approximately 20 m resolution (Government of Canada, Natural Resources Canada 2016).

## Methodology

Bathymetric data used for this study were collected during the research cruise MSM66 with the German RV *Maria S. Merian* in 2017. The expedition was conducted by the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) in Bremerhaven, Germany, and the Center for Marine Environmental Sciences (MARUM) in Bremen, Germany. With the permanently installed 12 kHz Kongsberg Simrad EM 122 multibeam echo sounder, 163 survey hours (2760 km track length) of bathymetric data were collected. The data were recorded with an aperture angle of 130° and a mean survey speed of 9 knots. Throughout the survey, 11 well distributed CTD measurements were conducted for sound velocity corrections. The acquired multibeam data were cleaned from major outliers and corrected for navigation, attitude and refraction errors along the shelf edge. From the cleaned data, a DEM was generated with a resolution of 5 m (Fig. 2).

The terrestrial data sets were merged to a single model. The ArcticDEM with a 5 m resolution served as the base elevation model. Gaps and holes were filled with the ArcticDEM with a 2 m resolution. All residual gaps were filled using the CanadianDEM after it was resampled and reprojected to fit the specifications of the ArcticDEM.

Due to the fact that the bathymetric data did not reach the shore and the satellite imagery data did not penetrate the water surface, a gap at the transition was always present that needed to be interpolated to prevent sharp edges. The transition within the fjord was relatively narrow ranging, from 30 m to 1000 m and was, thus, linearly interpolated. However, to prevent negative effects i.e. the artificial connection of islands to the mainland, in several locations, negative elevation values were applied to maintain the correct position of islands and the shoreline. IBCAO data was used for the remaining shelf region seaward of approximately 1000 m offshore. Finally, all data sets were merged into a DEM for the VR software (game engine).

The final DEM was imported in the game engine Unreal Engine 4 (UE4) as a tiled landscape with 128 tiles each consisting of 2017 × 2017 pixel and 8 million triangles. However, since visualising 128 tiles with a resolution of 5 m would have resulted in massive computational issues, level streaming was introduced. Level streaming is a method that only loads relevant tiles into memory and unloads all tiles with a specific distance from the user. In this way, the entire landscape is still visible but distant tiles receive a triangle reduction of 99.97 % reducing the memory consumption enormously.

Within Unreal Engine 4, environmental effects such as lightning, moving water surface, flowers and grass blowing in simulated wind as well as seagulls were programmed to achieve a natural and realistic look (Fig. 3).

**Fig. 3:** Landscape scenery in UE4 with the natural terrestrial colouration, foliage and the water surface

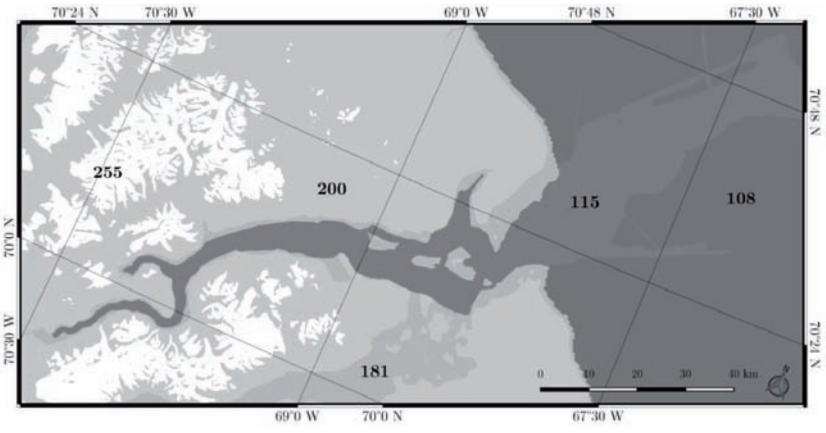

**Fig. 4:** Splat map with greyscale values for MSM66 bathymetry data (115), IBCAO data (108), transition (181), the terrestrial terrain (200) and glaciers implemented from the Randolph Glacier Inventory data set (255) (RGI Consortium 2017)

The landscape was designed to allow the user to switch between several different colourations. Therefore, a splat-map was generated which colour codes information to ensure a correct placement and blending of textures. In this study, five terrain features were extracted for texturing (Fig. 4). For the terrestrial terrain, the user can choose between a natural and a greyscale texture. The bathymetric data can be either coloured in greyscale as well, according to backscatter values or in rainbow colours representing water depth. To differentiate the MSM66 bathymetric data from the transition zone and the IBCAO bathymetry, the latter were illustrated in dark grey (Fig. 5 and Fig. 6).

To navigate within the virtual space, locomotion systems were developed to either fly or walk in the proximity and to teleport to distant locations. The application also contains measurement systems to determine the elevation, distance to a point as well as height difference and slope measurements between two set points (Fig. 7 and Fig. 8).

## Consideration of usability, utility and limitations

The usability and utility were assessed based on a user survey with representatives from the field of hydrography and geology. Each interviewee (study participant) had time to use the VR application for 30 minutes and had to complete a questionnaire afterwards.

The handling and user-friendliness of the VR application were perceived as overall pleasant. All interviewees found the application easy to use and nobody felt motion sick or uncomfortable.

Regarding the utility, all users received an improved impression of the terrain data compared to 2D presentations. Also, all functionalities and measuring tools seemed to help the viewer to get necessary information from the terrain and were useful to seize the dimensions. Some participants stated that VR could be beneficial for certain forms of quality analyses since outliers can be very easily detected. Also, VR can be helpful for the interpretation of the terrain, especially regarding backscatter analyses. Backscatter infor-

**Fig. 5:** Landscape scenery in UE4 without the water surface depicting the Hillshade colouration for both the terrestrial as well as the bathymetry terrain. The interpolated dark grey transition zone is clearly visible

**Fig. 6:** Landscape scenery in UE4 without the water surface depicting the Hillshade colouration for the terrestrial terrain and the depth related rainbow colouration for the bathymetry. In this presentation, the rainbow colour ramp stretches from –100 m until –450 m

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mation can be draped above the 3D terrain allowing for correlations between sound intensity values and slope of the terrain. Furthermore, a 3D visualisation of terrain data provides a helpful tool to interpret measurements and information in the real spatial context. For example, the inclination of the terrain and the dimension of morphological landforms can be captured more intuitively.

A great disadvantage of the used game engine over traditional 2D and pseudo 3D GIS software packages is the very limited possibility to import or export geospatial data sets. Raster data sets cannot be imported with spatial reference since no coordinate transformation algorithm is implemented. The only way to provide a sort of spatial link is to import raster data sets with the same extent, scale and position as the terrain in UE4. Also, the whole hardware and project setup is very time-consuming.

## Conclusion

In conclusion, this study presents a method for visualising large, high-resolution terrain models above and below the water surface in VR. The application was perceived as overall user-friendly and users received an increased perception of the terrain and distances compared to 2D representations. However, there are some major limitations of the game engine concerning the poor import and export possibilities and the lack of a spatial reference systems. Nevertheless, the potential for VR visualisations was demonstrated. Certainly, VR has great capabilities for a variety of hydrographic applications in the future given that the above-mentioned limitations can be overcome. //

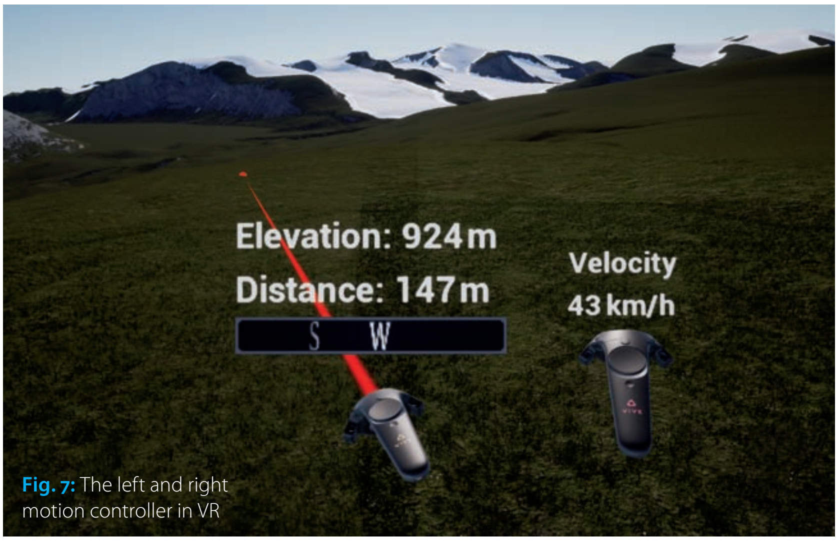

**Fig. 7:** The left and right motion controller in VR

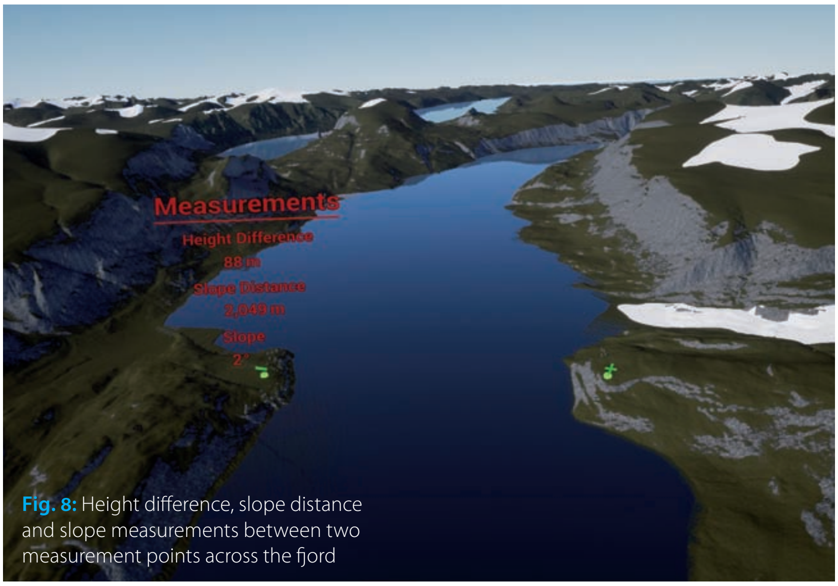

**Fig. 8:** Height difference, slope distance and slope measurements between two measurement points across the fjord

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c/o Sabine Müller
Innomar Technologie GmbH
Schutower Ringstraße 4
18069 Rostock

Internet: www.dhyg.de
E-Mail: dhyg@innomar.com
Telefon: (0381) 44079-0

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**Chefredakteur:**
Lars Schiller
E-Mail: lars.schiller@dhyg.de

**Redaktion:**
Peter Dugge, Dipl.-Ing.
Horst Hecht, Dipl.-Met.
Holger Klindt, Dipl.-Phys.
Dr. Jens Schneider von Deimling
Stefan Steinmetz, Dipl.-Ing.
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