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Research Results :

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Related Sites

SEABED 2030 · THE NIPPON FOUNDATION · GEBCO · IHO International Hydrographic Organization · UNESCO · Intergovernmental Oceanographic Commission

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Mathematical Seafloor Geomorphology

Advancing Our Understandings for the Earth :

JAMSTEC

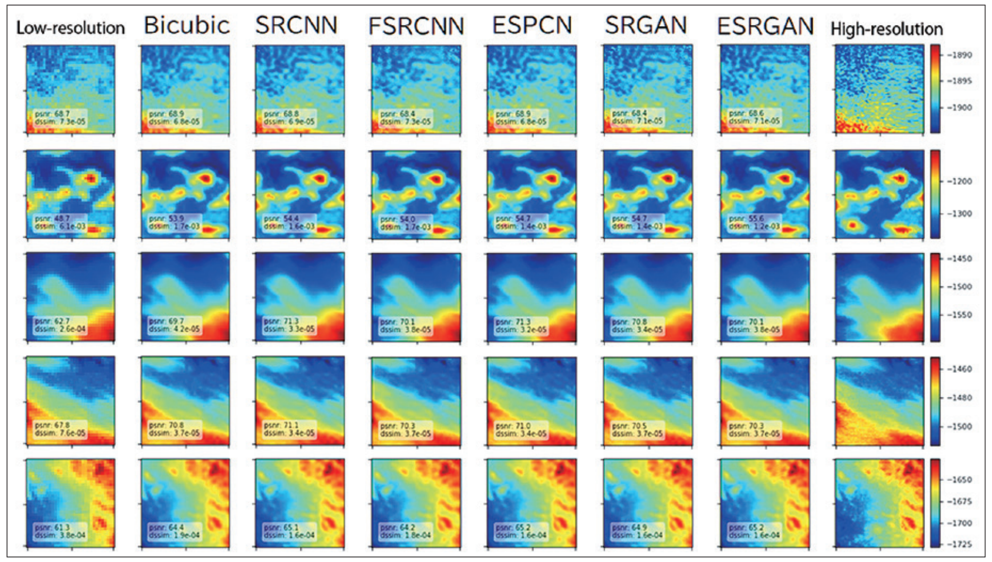
Introduction

The Mathematical Seafloor Geomorphology Research Project, which started in 2019, has been working on increasing the resolution of bathymetric image analysis using deep learning and advancing the sophistication of seafloor topography image analysis by sparse modeling. In the future, we will further develop these analysis methods and integrate the bathymetric structure patterns obtained through image feature extraction with knowledge from various natural domains such as disaster prevention, environment, living organisms, and resources, from which we expect to understand the origin of seafloor topography and its effects on the natural domains. The image analysis method established in this research project makes it possible to create detailed bathymetric data for the same area from existing rough bathymetric data. This will make a significant contribution to the Nippon Foundation-GEBCO Seabed2030 project by applying it to ocean areas where insufficient data is collected.

Super-resolution for ocean bathymetric maps using machine learning approaches

Recently, deep learning, a machine learning method that uses multi-layered neural networks, has been attracting attention in various research and industrial fields. In particular, deep convolutional neural networks (DCNNs), which specialize in image recognition, have been remarkable at extracting features from a large amount of data. They have achieved highly significant performance, which is far exceeding that of conventional methods in image classification, object detection, anomaly detection, and image super-resolution. Image super-resolution, which is the processing of converting low-resolution images into high-resolution ones, is performed by learning the corresponding transformation process.

In this research program, we implemented five different DCNN architectures (SRCNN, FSRCNN, ESPCN, SRGAN, and ESRGAN) for image super-resolution and tuned them for the topographic maps of the middle Okinawa Trough acquired by JAMSTEC. The figure below shows an example of super-resolution of a 100-m mesh bathymetry map to a 50-m mesh, for a 3.2-km-square area. The super-resolution results of all architectures showed better accuracy than that of bicubic interpolation, especially in the case of rugged terrain and missing values. We are currently improving the generalization performance and magnification factor of DCNNs, to enable their application to a wider range of areas, as well as developing those which incorporate bathymetric knowledge.

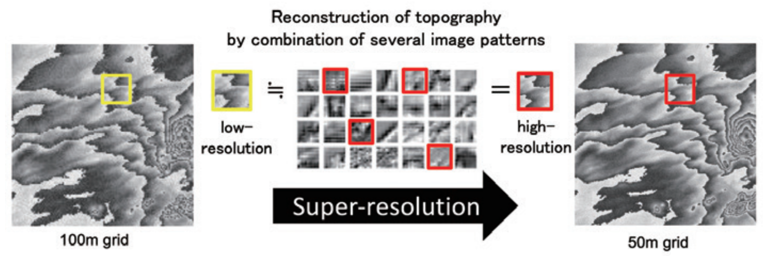


Extraction of image feature quantity using machine learning

Sparse modeling is a mathematical and information-scientific methodology which assumes that observed high-dimensional data can be represented by a small number of essential variables. Because the sparse modeling enables maximum information extraction even from a small amount of data, it is applied to various problems including high-speed imaging of medical MRI and direct observation of black holes. In this research program, we think that sparse modeling would be effective for the analysis of seafloor geomorphology. In other words, the problem is the same as the imaging of the MRI and the observation of black holes, and by making effective use of limited available data as much as possible, the original seafloor geomorphology can be accurately obtained.

By improving the previous methodologies so that it can be applied to image data in natural science and applying it to seafloor topographic maps, we clarified that it is possible not only to improve the resolution but also to automatically capture spatial patterns such as microtopography that are characteristic of the target area. At present, we are trying to link the obtained characteristic geomorphologic patterns with knowledge of geology and biology, in order to contribute to several important scientific issues, such as disaster prevention, resource exploration, and environmental problems.

Recently, we have been developing a point cloud data analysis method that applies sparse modeling to multibeam bathymetric data, which is the primary data for creating seabed topographic maps. So far, it has been found that by training appropriate supervised data, we can automatically remove noise that occurs for various reasons. Currently, by combining these analysis methods, we continue our research and development with the goal of constructing a framework that can create high-precision, high-resolution seabed topographic maps, even in marine areas where it is difficult to obtain good quality bathymetric data.



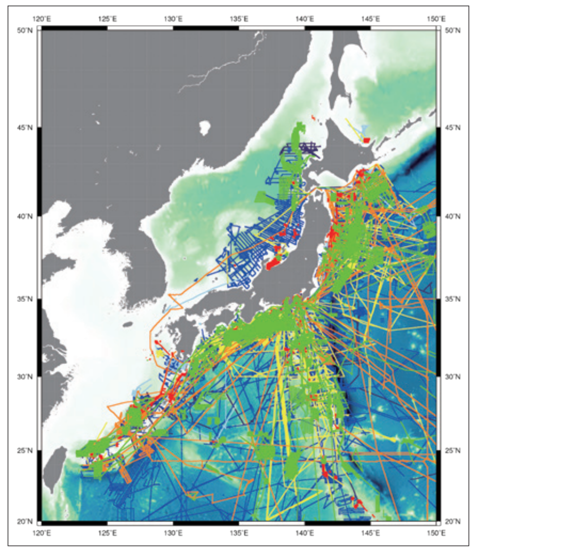
Contribution to the Nippon Foundation - GEBCO Seabed2030 Project

GEBCO aims to provide the most authoritative, publicly available bathymetry of the world's ocean. It operates under the joint auspices of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The GEBCO Chart series originated from its initiation by Prince Albert I of Monaco in 1903. The development of GEBCO has covered 24.9% of the world's oceans to date (based on the press release in May 2023), leaving three-quarters of the survey blank yet. To map the gaps, oceanographic experts from hydrographic associations, and related organizations in Europe, the United States, Asia, and Oceania have held meetings regularly and updated the bathymetric chart. One of the meetings, namely the Regional Mapping Community Meeting, was attended by the regional and global centers of Seabed 2030. The meeting agenda included championing mapping activities, assembling and compiling bathymetric information, in collaboration with existing mapping initiatives within the sea area in charge.

GEBCO WEEK is a series of meetings held once a year, over the duration of a week, that calls for pre-registration and widespread participation from marine -related researchers, governments, private sectors, and media, by providing meeting and symposium information. During GEBCO WEEK, reports and discussions on the status of bathymetric data collection, introduction to new analysis software along with a brief training, and outreach activities to make Seabed 2030 widely known have been carried out in plenary sessions and subcommittees.

The JAMSTEC post-processed bathymetry data are publicly available and was provided to the National Institute of Water and Atmospheric Research (NIWA), which is the Seabed 2030 regional center responsible for compiling the bathymetric map of the South and West Pacific Ocean. Attempts to convert low-resolution bathymetry images to higher-resolution ones by machine-learning approaches (Kikawa et al., AGU2023 Fall Meeting) and AUV (Autonomous Underwater Vehicles) development to obtain higher quality data from wider areas have been made, which are expected to greatly contribute to Seabed 2030.

The Seabed 2030 Project aims to cover 100% of the world's ocean floor by the year 2030. To achieve this goal, an integrated data collection methodology has been initiated, which involves the private sectors, especially fisheries, through a newly organized Seabed 2030 crowd-sourced bathymetry working group, and the currently formed automatic data transfer systems.



Track chart of bathymetric surveys around Japan conducted by 7 JAMSTEC fleets (KAIREI, NATSUSHIMA, YOKOSUKA, KAIYO, MIRAI, KAIMEI and SHINSEI MARU).The color of the track lines is as follows: Blue=KAIREI, Red=NATSUSHIMA, Green=YOKOSUKA, Yellow=KAIYO, Orange=MIRAI, Purple=KAIMEI, Skyblue=SHINSEI MARU. Data provided by Research Data Publish Technology Group, Center for Earth Information Science and technology (CEIST), JAMSTEC.