Advisory Opinion

Visualization Facilitating Scientific Knowledge Making —Transdisciplinary Digital Visual Thinking Based on Visual Analysis of Big Data

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Science Council of Japan

Subcommittee on Visualization Facilitating Scientific Knowledge Making
Committee on Comprehensive Synthetic Engineering

This advisory opinion is the result of the deliberations of the Subcommittee on Visualization Facilitating Scientific Knowledge Making Committee on Comprehensive Synthetic Engineering of the Science Council of Japan.

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This English version is a translation of the original written in Japanese.

Executive Summary

1 Background

Based on the Recommendation titled *Toward Visualization Facilitating Scientific Knowledge Making* issued by the Joint Subcommittee on Computational Science Simulation and Engineering Design of the Committee on Comprehensive Synthetic Engineering and the Committee on Mechanical Engineering in the 23rd term and the report titled *Toward Visualization Facilitating Scientific Knowledge Making: Arts and Sciences Fusion Research and Formulation of New Paradigms* issued by the Subcommittee on Visualization Facilitating Scientific Knowledge Making of the Committee on Comprehensive Synthetic Engineering in the 24th term, the Subcommittee on Visualization Facilitating Scientific Knowledge Making in the 25th term has focused on practices of proposals in these reports centered around the three Working Groups' activities on the Formulation of New Visualization Paradigms, Visualization to Promote Arts and Sciences-Fused Research in the ICT Age, and Visualization for the Benefit of Society. We specifically propose the creation of a new interdisciplinary academic research based on big data visualization and the provision of a digital visual thinking environment.

2 Necessity for Interdisciplinary Visualization in Light of the Big Data Era

Today, *big data* is extensively generated through high-performance computing, large-scale measurements, and online data collection, impacting not only natural sciences but also fields like cultural heritage preservation and data journalism. In various research areas, there are some cases where digital big data has become the primary source, that is there are some cases where no materials including documents and diagrams other than big data exist. Because of this shift, there are strong requirements for establishing interdisciplinary academic research that leverages these unique characteristics.

Visualization is crucial for comprehending and extracting information from complex big data. It serves as a shared language, enabling collaboration among researchers from diverse fields in analyzing and utilizing daily generated big data. However, field-specific visualization may be influenced by users' environments and preferences, leading to biased interpretations. Therefore, there is an urgent need to establish a standard model for interdisciplinary visual analysis and to create "a digital visual thinking environment" based on this model.

3 Digital Visual Thinking Paradigm Establishment and Infrastructure Construction

This advisory opinion proposes *visual thinking* as a new *interdisciplinary academic research based on big data visualization*. Visual thinking has the potential to provide a fundamental infrastructure, like search Web, enhancing daily thinking activities by utilizing big data.

(1) Visual analysis of big data in scientific computing

As stated at the beginning of the *Visualization in Scientific Computing* report (1987), visualization is a kind of computing. Every computing requires its own paradigm, and visualization is no exception. The Visualization Discovery Process (VDP), which was proposed in the *Visualization Research Challenge* report (2006), is a paradigm based on a human-in-the-loop for visual analysis of big data and is widely recognized as the current standard paradigm for interactive visualization. On the other hand, deep learning, which has recently been making remarkable progress, may have a significant impact on visualization. We herein propose a digital visual thinking infrastructure as a next-generation paradigm for scientific visualization that combines deep learning with the VDP process of acquiring new knowledge from visualized images through the user's perceptual and cognitive mechanisms and the exploration process of adding new specifications fed back to visualization based on the acquired knowledge.

(2) Visual analysis of big data in cultural and art sciences

In recent years, big data has been applied in cultural and art sciences, involving tasks such as 3D scanning of archaeological sites and motion capture data for dances. Subcultures like manga, animation, and games also utilize big data through metaverse and AI support. Challenges include “data diversity” and “data uncertainty” due to measurement noise in acquiring data from the real world. The digital visual thinking infrastructure in this field should handle multi-source data, leveraging richness of information in large-scale datasets and good compatibility with statistical processing. This approach establishes a new way of fusing humanities and sciences research.

(3) Visual analysis of big data in social sciences

Computational social science is rapidly growing, leveraging advanced technologies and big data for social analysis. Developing visual analysis

technologies is crucial for advancing human intelligence enabling meaningful insights of complex societies. Integrating computational social science and visual analysis technology establishes new methodologies of *data journalism*. Adopting an informatics approach in data journalism broadens people's interest in data analysis, contributing to objective understanding social phenomena.

4 Comprehensive Synthetic Engineering Vision toward the Integration of the Humanities and Sciences

The visual thinking infrastructure proposed here becomes useful in a very wide range of fields. Natural science primarily deals with physical space and abstract space data, cultural and art sciences physical space data and social science abstract data space. These cover the typical types of dealing with big data. The idea of visual thinking, independent of the kind of big data, can serve various fields through a common framework. Interdisciplinary collaboration and cocreation using this infrastructure strongly supports the humanities and sciences fusion in the big data era. Achieving this vision involves integrating consensus-building mechanisms and expanding visualization literacy education, for which the digital visual thinking infrastructure is available.