Research area in Strategic Objective *"Innovation in measurement and analysis processes aimed at solving social issues"*

Creating innovative measurement and analysis systems aiming to solve social issues

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Overview

As the expression "Measurement is the mother of science" suggests, progress in science and technology begins with "seeing and noticing." The history of advances in science and technology can also be called the history of advances in measurement technology.

In resolving global social challenges such as the SDGs, beginning with becoming carbon neutral by 2050, it will be essential to develop various new practical materials, including from the standpoints of energy and recycling. At the front lines of leading science and technology research, the subjects of the research are shifting toward grasping and understanding the peculiarities of complex, uneven layered structures and substance changes. Understanding complex substances and phenomena like this is hardly achieved by simply improving conventional measurement technology or similar strategies, and so breakthroughs in measurement and analysis methods are essential.

In this research area, our aim is to bring about sophisticated advances in measurement and analysis methods and generate new measurement and analysis systems that are capable of resolving actual and various difficult challenges in measurement and analysis by combining advances in measurement technology with information technology such as advanced mathematical modeling and machine learning. We also aim at innovating measurement and analysis processes to offer Japan's research environments advantages over the coming 10 or 20 years. Moreover, the effectiveness of the new measurement and analysis methods produced in this research area should be verified in the real-world situation such as the development of actual new materials, and their generality should be explored in other research and development fields that face similar difficulties beyond the original target fields. More specifically, the research will position "boundary-breaking advanced measurement," "adaptation of measurement data informatics," and "multiscale/multimodal measurements, and their use case development" as key

research components, and will pursue measurement and analysis innovations by realizing a research environment that merges these components.

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Area

1. Basic Objectives

(1) Innovation in measurement and analysis methods

By combining measurement and information technologies, we aim to innovate highly versatile methods of measurement and analysis that enable the acquisition of hitherto unobtainable measurement data and the analysis of previously incomprehensible results for a wide range of problems.

(2) Application to real-world problems

Rather than simply producing the world's best measurement results in a benchmark environment, we aim to achieve breakthroughs in diverse real-world social and practical issues using highly versatile technologies and methods as well as identify and develop specific technologies and methods needed to solve these difficult problems while adapting them to real-world problems to show their efficacy.

(3) Research and development that contributes to innovation across measurement, analysis, and practical application processes

We are conducting research and development to link, as a series of processes, observation and measurement as well as understanding and analysis for use in a variety of practical applications.

(4) Use of interdisciplinary measurement techniques

Our aim is the acquisition of general-purpose technology that advances one field and can be used in others.

(5) Research and development that contributes to international competitiveness

We expect that the results achieved in this area will lend Japan international competitive advantage for the next ten or even twenty years.

2. Specific Examples of Research

To achieve the above aims, the main research elements in this area are "boundary-breaking advanced measurement," "adaptation of measurement data informatics," and "Multiscale/multimodal

measurement, and their highly versatile use case development.' The following are examples of individual research projects, but it is extremely important that these are closely linked to achieve truly useful innovations in measurement and analysis. The projects discussed below are examples, and a wide range of other proposals are invited.

(1) Boundary-breaking advanced measurement

Research required to solve our target issues, research that makes the currently unmeasurable (unobservable) measurable (observable), and research that offers broad ripple effects to solve problems both in a specific field of measurement and analysis and in numerous other fields. We are promoting synthetic research that brings together new measurement principles and devices with novel, suitable informatics to push the limits of advanced measurement, rather than research that merely combines the development of new measurement principles and devices with existing informatics analysis.

Examples of things we wish to be able to measure (observe) are as follows:

(a) Time-variant measurements of non-uniform distributions and states at various scales
(b) Compatibility of temporal and spatial resolutions
(c) Measurement and tracking of components buried in noise, and establish reproducibility of measurements
(d) Achieve precise measurement of internal and boundary states and their changing phenomena
(e) Time-variant measurement of phenomena and state distributions that occur in conjunction at different scales, and clarification of their mechanisms (multi-scale measurement and analysis)
(f) Simultaneous measurement and analysis of different properties and their relationships (multimodal simultaneous measurement and analysis)

(2) Adaptation of measurement data informatics

Even after pushing past the limits of measurement, there are cases where the results, regardless of the field, are sufficiently complex such that they are no longer things that people can directly understand, and examples where the measurement and analysis process has become too complex for its design and control to be optimized. Therefore, to solve our target problems and handle phenomena that are too complex for humans to understand intuitively, we are conducting research to achieve breakthroughs by integrating measurement science with information science, mathematical statistics, and computational science. To maximize performance of measurement and analysis needed to solve our target problems, we are using information science, mathematical statistics, and computational science to establish methods for optimal design and control of the structure and parameters of measurement and analysis processes.

Specific examples of studies include the following.

(a) The development of an integrated system for target non-uniform states and phenomena that combines precision measurement technology generating large volumes of 3D data with machine learning and simulation technology to discover latent correlations in the data and propose hypotheses in a single uniform flow from measurement to hypothesis.

(b) Development of methods for high-accuracy analysis of the structures and processes of unfamiliar subjects in short time spans by optimizing measurement points using existing measurement data for similar subjects as training data.

(c) Development of AI-mediated measurement methods to predict subsequent measurement data based on previously obtained data and propose more appropriate measurement conditions based on these predictions during measurement experiments

(3) Multiscale/multimodal measurement, and their highly versatile use case development

Phenomena occurred in different real-world measurement subjects, including new applied materials, new energy processes, new biochemical processes, and other new phenomena, that possess complex behavior with a hierarchy of spatiotemporal sizes ranging from the micro to macro scale, and that involve not only mechanical elements, but also multiple elements such as electric potential, magnetic fields and temperature distributions. These phenomena cannot be analyzed and understood totally using physical quantities at a single scale by a single method of measurement.

Although the resolution and other capabilities of measurement technologies have advanced, research on integrated analysis and understanding of the results of multiscale and multimodal measurement has only just started. We aim to develop understanding of new applied materials, new energy processes, new biochemical processes, and other new phenomena, and develop use cases needed to solve our target societal real-world problems.

Specific examples of studies are as follows:

(a) Realizing next-generation functional materials in a wide range of fields, as well as next-generation energy, alternatives to rare materials, new foodstuffs, etc.

(b) Achieving recycling and upcycling in a wide range of fields

(c) Realizing productivity improvement solutions across a wide range of fields

(d) Realizing energy efficiency improvements in diverse fields

(e) Achieving longer service life, higher reliability, and improved safety of products, systems, and social infrastructure in various fields

3. Research area management

(1) Advisor Team

Because this is a highly challenging combined field of research that demands knowledge of various types of measurement technology, hands-on expertise with various forms of real-world development, and a broad understanding of informatics, a portfolio of advisors will be assembled from across the industry, including research areas such as real-world developments, measurement technologies, and informatics, to manage the research team.

(2) Promoting Interdisciplinary Exchange

To achieve innovation in measurement and analysis beyond a specific field, fora will be established for exchanges between researchers and companies, and between researchers working with different measurement and analysis technologies or with different subjects and areas of application. Interdisciplinary exchange will drive the creation of innovative measurement techniques and use-case development. Collaboration with other related research areas will also be promoted. International symposia will be organized, offering guest lectures from relevant researchers considering international research trends.

4. Research Period and Costs

The research period shall be limited to no more than five and a half years. Research costs (direct costs) submitted include the costs required to achieve the proposal content, with an upper limit of ¥240 million. Applications in excess of this sum may nonetheless be approved in cases where genuine need is recognized due to the content and character of the research. Please note that research costs may be adjusted during selection, subject to scrutiny by the supervisor.

5. Selection Policy

The selection process will focus on the following criteria:

(1) The proposal must be novel and original, creating innovation in various measurement and analysis processes.

(2) The proposal must solve a real-world concrete social issue or practical problem, rather than an abstract one, and must illustrate the content of the problem or issue with concrete examples.

(3) The proposal must be based on the results achieved within the research period and must indicate a specific scenario that will lead to resolving the specific issue or problem mentioned above.

(Note that it is not necessarily required to solve societal challenges using a specific product or to create a commercially viable product such as a measurement device within the research and development period of this program.)

6. Points to Note for Applications

(1) Scale and versatility of research subjects

This area expects innovation of highly versatile methods of measurement and analysis that can be applied across diverse fields to measure and analyze phenomena across various scales. Simultaneously, it is expected that proposals will clarify the specific measurement and analysis functions required to solve target problems and aim to achieve them. Particularly, it is expected that proposals will push the limits of measurement through the fusion of new measurement principles and equipment with novel informatics. Proposals are expected to establish methods for the optimal design and control of structures and parameters of measurement and analysis processes by drawing on information science, mathematical statistics, and computational science, and to maximize required performance.

(2) Formation of Project Teams

In this research area, to achieve innovations in measurement and analysis and confirm their efficacy in real-world applications through the close linkage of "Boundary-breaking advanced measurement," "Adaptation of measurement data informatics," and "Multiscale/multimodal measurement, and their use case development," these three elements are expected to be brought together under a single research director.

To this end, it would be useful to have participation of not only measurement science researchers, but also experts in information science (mathematical modeling, machine learning, etc.).

However, originality and challenge should not be sacrificed by overemphasizing linkage among these three elements.

Therefore, we are willing to select teams covering one or two research elements, provided they satisfy the requirements set out in "5. Selection Policy."

In any case, we recognize the importance of linking multiple elements in this research area; so, we ask that proposals include or refer to such linkage.

In addition, this research area aims to solve diverse societal and practical problems through interdisciplinary research and development. As such, we may ask you to consider collaborative research with other teams in the research area during the research period.

(3) Items to be included in proposals

In accordance with the aims and selection policy of this research area, in addition to technical contents, each of the following items should be clearly indicated in proposals:

(a) What is the real-world concrete social issue or practical problem, rather than an abstract one, that you wish to solve? Indicate concrete examples of the content of this problem?

(b) What are the measurement and analysis challenges that you wish to solve?

(c) Illustrate, by way of an example, specific scenarios that lead to resolving the concrete social

issue or practical problem set out in (a) by solving the challenges set out in (b)

(d) How will the front lines of research and development and applied technology development change in Japan over the next 10–20 years, and how do you want to change them?

(e) Will the proposed method of measurement and analysis yield results not only in a specific field (e.g., specific materials, specific substances), but also generally across diverse fields, and why?