Speaker: Naoki Hamada (Engineering Division, KLab Inc.)
Title: Mathematics for Evolutionary Computation
Abstract: Evolutionary computation is a black-box optimization algorithm that does not require convexity or derivatives of the optimization problem. It has been widely used in various industrial problems because it can often approximate the global optima with good accuracy. However, even now, most of its working principles are not mathematically understood, and the benchmark-intensive development of algorithms is beginning to face problems. In this talk, I will introduce methods and applications of global analysis, especially singularity theory of differentiable mappings, which seems to be promising as a theory of global optimization for evolutionary computation.

Speaker: Akira Oyama (Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency)
Title: Introduction to multiobjective evolutionary algorithm
Abstract: Multiobjective evolutionary algorithm (MOEA) has excellent features such as being able to obtain global optimum solutions and being able to obtain Pareto-optimal solutions for a multi-objective optimization problem. In this talk, basics and applications of MOEA are introduced for those who have not dealt with MOEA so far.

Speaker: Goo Ishikawa (Department of Mathematics, Faculty of Sciences, Hokkaido University)
Title: Singularity theory: viewpoints, methods and applications
Abstract: A point where the situation of the space/figure, or the behaviour of the function/mapping looks very different from nearby points, is called a singular point. Singular points have a significance by showing local-global information of objects under the study. Regarding singularity theory as one of mathematical area, I would like to explain about several central problems of singularity theory, stability, genericity, determinacy, classification and recognition problems, the methods of bifurcation diagrams and stratifications, and so on, and thus, introduce some of geometrical approaches and characteristic viewpoints from singularity theory to try to find its possible applications.

Speaker: Shinichi Shirakawa (Faculty of Environment and Information Sciences, Yokohama National University)
Title: Probabilistic Model-Based Evolutionary Computation and Its Applications
Abstract: This talk focuses on evolutionary computation methods for solving an optimization problem by updating a probability distribution for generating solutions based on the objective function values. We overview the relation of such probabilistic

model-based evolutionary algorithms to stochastic natural gradient methods and their mathematical perspective. Several applications of probabilistic model-based evolutionary algorithms, such as neural architecture search, are also presented.

Speaker: Hiroshi Teramoto (Department of Mathematics, Faculty of Engineering Science, Kansai University)
Title: Local Structures of Pareto Sets and Fronts and Their Bifurcations
Abstract: In this talk, we assume objective functions and functions defining feasible sets are smooth. First, we classify local structures of feasible sets up to diffeomorphism. In the most generic class, Kuhn-Tucker's constraint qualification is satisfied but that is not necessarily the case for other degenerated classes. By using the classification, we discuss their bifurcations. Second, we classify maps defined by objective functions under Pareto-A equivalence preserving feasible sets and discuss their bifurcations. This is a collaborative research with Naoki Hamada (KLab Ltd.) and Kenta Hayano (Keio University).

Speaker: Danilo Vasconcellos Vargas (Faculty of Information Science and Electrical Engineering, Kyushu University; Department of Electrical Engineering and Information Systems, School of Engineering, The University of Tokyo)
Title: State-of-the-art Multi-objective Optimization with the SAN (Subpopulation Algorithm based on Novelty)
Abstract: Subpopulation Algorithm based on Novelty (SAN) is the arguably the current state of the art in multi-objective optimization. The reason for such a good result lies on using a novelty subpopulation to combine as well as keep track of previous solutions. In this manner, it is possible to each step further expand the search in yet new directions.

Speaker: Shunsuke Ichiki (Department of Mathematical and Computing Science, School of Computing, Tokyo Institute of Technology)
Title: Application of singularity theory to strongly convex multiobjective optimization problems
Abstract: In the industrial world, it is important to optimize several objectives such as cost, quality, safety and environmental impact. A multiobjective optimization problem is an optimization problem for such several objective functions. In this talk, first of all I introduce a topological property of the set of optimal solutions of a strongly convex multiobjective optimization problem. After that, as a main topic of this talk, I give an application of singularity theory to the problem.

Speaker: Yusuke Mizota (Faculty of Science and Engineering, Kyushu Sangyo University)
Title: All unconstrained strongly convex problems are weakly simplicial
Abstract: A multi-objective optimization problem is C^0 weakly simplicial if there exists a continuous surjection from a simplex onto the Pareto set such that the image of each subsimplex is the Pareto set of a subproblem. In this talk, we show that all unconstrained strongly convex problems are C^0 weakly simplicial. As an application of this theorem, we reformulate the elastic net as a non-differentiable multi-objective strongly convex problem and approximate its Pareto set and Pareto front by using a Bezier simplex fitting method, which accelerates hyper-parameter search. (Joint work with Naoki Hamada and Shunsuke Ichiki)

Speaker: Kenta Hayano (Department of Mathematics, Faculty of Science and Technology, Keio University)
Title: Weak Pareto optima are Pareto optima for simplicial problems
Abstract: For lots of real-world problems, the sets of Pareto optima have the shape of a simplex and their faces are Pareto optima of sub-problems. Such a problem is called a simplicial problem. In this talk, we show that weak Pareto optima are Pareto optima for simplicial problems using a topological method.

Speakers: Reiya Hagiwara (Kyushu University), Naoki Hamada (KLab Inc.), Takahiro Yamamoto (Tokyo Gakugei University), Daisuke Sakurai (Kyushu University)
Title: Reeb Space-Based Design of Benchmark Problems for Multi-Objective Optimization
Abstract: When studying solvers for optimization problems, evaluation is an important task - this is especially true for multi-objective optimization, where the evaluation is itself a research topic. For this purpose, a wide range of studies have been conducted on constructing benchmark problems; yet, it has remained to be incredibly challenging to control the difficulty of the benchmark. In this context, we present our ongoing study to achieve the required control, adapting the singularity theory as the basis. The proposed approach is made possible thanks to the relationship between the singularity theory and Pareto optima, which is the extension of optimum solutions in usual optimization problems. Although this relationship has been known for a while, we stand on the point of view of differential topology and Reeb space theory to construct a new mathematical model to describe the behavior of a solver. When designing the benchmark problem, one can control the multi-modality of multi-objective optimization problems. According to our view point, the modality consists of factors such as (i) regions in which the solver tends to be trapped around global and local optima and (ii) how one such includes another. In the presentation, we provide a rather rough introduction to the mathematical background, including recent research directions, and discuss the progress and outlook.