Nonconvex.jl: A Comprehensive Julia Package for Non-Convex Optimization

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July 13, 2023

Abstract

Non-convex optimization is a critical task in numerous fields, ranging from machine learning to engineering and economics. Nonconvex.jl is a powerful Julia package that provides an extensive toolkit for solving non-convex optimization problems. This paper explores the features and capabilities of Nonconvex.jl, highlighting its integration with various optimization libraries, including Ipopt.jl, NLopt.jl, NonconvexMMA.jl, Percival.jl, Juniper.jl, Pavito.jl, Metaheuristics.jl, NOMAD.jl, Hyperopt.jl, NonconvexBayesian.jl, and NonconvexSemidefinite.jl. These integrations allow users to efficiently address complex optimization challenges and explore diverse solution landscapes.

1 Introduction

Non-convex optimization involves finding global or local minima/maxima of objective functions that are not convex. It is a challenging task due to the presence of multiple local optima and increased complexity. Nonconvex.jl[1] aims to simplify this process by providing a comprehensive package that combines the functionality of several optimization libraries within the Julia ecosystem.

2 Features of Nonconvex.jl

2.1 Problem Definition and Constraints

Nonconvex.jl offers an intuitive interface for defining optimization problems, allowing users to specify objective functions and constraints concisely. It supports

[1] `https://github.com/JuliaNonconvex/Nonconvex.jl`

various problem types, including unconstrained optimization, constrained optimization, nonlinear programming, mixed integer programming and semidefinite programming.

2.2 Optimization Algorithms

Nonconvex.jl seamlessly integrates multiple optimization packages by wrapping them using a common interface, expanding the range of available algorithms and problem formulations. Nonconvex.jl uses automatic differentiation to get the gradients and optionally Hessians of the objective and/or constraint functions if required by the optimization algorithm. Custom gradients and Hessians can also be provided by the users. The following is a list of packages wrapped in Nonconvex.jl.

2.2.1 Ipopt.jl

Ipopt.jl[2] is a widely used Julia interface to the Interior Point OPTimizer (Ipopt). It provides efficient algorithms for nonlinear programming, including constrained optimization problems. Nonconvex.jl leverages Ipopt.jl's capabilities, enabling users to solve nonlinear optimization problems efficiently.

2.2.2 NLopt.jl

NLopt.jl[3] is another powerful Julia package for nonlinear optimization. It offers various local and global optimization algorithms, including gradient-based methods, derivative-free approaches, and stochastic search algorithms. Nonconvex.jl integrates NLopt.jl, providing users with a wide range of optimization options.

2.2.3 NonconvexMMA.jl

NonconvexMMA.jl[4] is a Julia package for non-convex optimization using the method of moving asymptotes (MMA). It offers efficient algorithms for solving constrained and unconstrained nonlinear optimization problems.

2.2.4 Percival.jl

Percival.jl[5] is a Julia package that implements the augmented Lagrangian for nonlinear programming. Nonconvex.jl wraps Percival.jl, allowing users to solve problems with many nonlinear, equality and/or inequality constraints.

[2] `https://github.com/jump-dev/Ipopt.jl`
[3] `https://github.com/JuliaOpt/NLopt.jl`
[4] `https://github.com/JuliaNonconvex/NonconvexMMA.jl`
[5] `https://github.com/JuliaSmoothOptimizers/Percival.jl`

2.2.5 Juniper.jl

Juniper.jl[6] is a powerful Julia package for solving mixed-integer nonlinear programming (MINLP) problems. Nonconvex.jl integrates Juniper.jl, providing users with the ability to solve non-convex optimization problems with mixed-integer variables.

2.2.6 Pavito.jl

Pavito.jl[7] is a Julia package which implements a gradient-based outer approximation solver for mixed integer programming.

2.2.7 Metaheuristics.jl

Metaheuristics.jl[8] is a collection of metaheuristic optimization algorithms in Julia. Nonconvex.jl wraps Metaheuristics.jl, enabling users to apply a variety of nature-inspired optimization techniques, such as genetic algorithms, particle swarm optimization, and simulated annealing, to non-convex problems with inequality, equality and integer constraints.

2.2.8 NOMAD.jl

NOMAD.jl[9] is a Julia interface to the NOMAD (Nonlinear Optimization by Mesh Adaptive Direct Search) library. It offers efficient algorithms for global optimization, handling black-box functions and constraints.

2.2.9 Hyperopt.jl

Hyperopt.jl[10] is a Julia package for hyperparameter optimization using global search and Bayesian optimization techniques. Nonconvex.jl incorporates Hyperopt.jl, enabling users use it for multi-start optimization to hyper-parameter optimize the initial solution passed to any other optimization algorithm.

2.2.10 NonconvexBayesian.jl

NonconvexBayesian.jl[11] is a Julia package for constrained surrogate-assisted non-convex optimization. Inequality, equality and integer constraints are supported. In this algorithm, Gaussian processes are used to formulate surrogates replacing expensive functions in the optimization problem. The cheaper subproblem then gets sequentially solved using any of the other available optimization algorithms.

[6] `https://github.com/lanl-ansi/Juniper.jl`
[7] `https://github.com/jump-dev/Pavito.jl`
[8] `https://github.com/jmejia8/Metaheuristics.jl`
[9] `https://github.com/bbopt/NOMAD.jl`
[10] `https://github.com/baggepinnen/Hyperopt.jl`
[11] `https://github.com/JuliaNonconvex/NonconvexBayesian.jl`

2.2.11 NonconvexSemidefinite.jl

NonconvexSemidefinite.jl[12] is a Julia package for nonconvex semidefinite programming. It provides an interior point algorithm for optimizing semidefinite programs with non-convex objective functions and/or constraints.

3 Use Cases and Applications

Nonconvex.jl finds applications in various domains, including machine learning, robotics, portfolio optimization, control systems, and more. With its diverse range of optimization algorithms, Nonconvex.jl provides researchers and practitioners with a powerful tool to address complex optimization challenges.

4 Conclusion

Nonconvex.jl is a Julia package that simplifies the solution of non-convex optimization problems. By wrapping multiple optimization libraries, including Ipopt.jl, NLopt.jl, NonconvexMMA.jl, Percival.jl, Juniper.jl, Pavito.jl, Metaheuristics.jl, NOMAD.jl, Hyperopt.jl, NonconvexBayesian.jl, and NonconvexSemidefinite.jl, Nonconvex.jl offers users a wide array of algorithms and problem formulations. The integration of these libraries empowers users to efficiently explore non-convex solution landscapes and find optimal solutions for various applications.

5 Acknowledgments

The author would like to acknowledge the contributors and developers of Ipopt.jl, NLopt.jl, Percival.jl, Juniper.jl, Pavito.jl, Metaheuristics.jl, NOMAD.jl, Hyperopt.jl, NonconvexSearch.jl and NonconvexSemidefinite.jl for their valuable contributions to the Julia optimization ecosystem. The author would also like to acknowledge ChatGPT for helping with the writing of this paper.

[12] `https://github.com/JuliaNonconvex/NonconvexSemidefinite.jl`