

PROPT - ONE OF A KIND, LIGHTNING FAST SOLUTIONS TO YOUR OPTIMAL CONTROL PROBLEMS!

NOW WITH WELL OVER 100 TEST CASES!

The PROPT software package is intended to solve dynamic optimization problems. Such problems are usually described by:

- A state-space model of a system. This can be either a set of ordinary differential equations (ODE) or differential algebraic equations (PAE).
- Initial and/or final conditions (sometimes also conditions at other points).
- A cost functional, i.e. a scalar value that depends on the state trajectories and the control function.
- Sometimes, additional equations and variables that, for example, relate the initial and final conditions to each other.

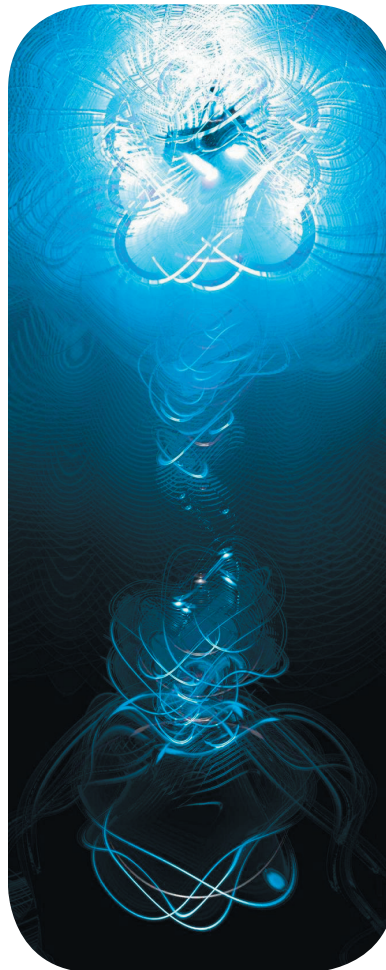
The goal of PROPT is to make it possible to input such problem descriptions as simply as possible, without having to worry about the mathematics of the actual solver. Once a problem has been properly modeled, PROPT will take care of all the steps necessary in order to return a solution.

When using PROPT, optimally coded analytical first and second order derivatives, including problem sparsity patterns are automatically generated, thereby making it the first MATLAB package to be able to fully utilize NLP (and QP) solvers such as: KNITRO, CONOPT, SNOPT and CPLEX.

PROPT currently uses **Gauss** or **Chebyshev**-point collocation for solving optimal control problems. However, the code is written in a more general way, allowing for a DAE rather than an ODE formulation. Parameter estimation problems are also possible to solve.

PROPT has three main functions:

- Computation of the constant matrices used for the differentiation and integration of the polynomials used to approximate the solution to the trajectory optimization problem.
- Source transformation to turn user-supplied expressions into optimized MATLAB code for the cost function f and constraint function c with two levels of analytical derivative!
- Functionality for plotting and computing a variety of information for the solution to the problem.



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Unique Features

- **Lightning Speed Solutions:** PROPT has firmly cemented its position as the fastest and most robust optimal control package. Previously tough problems are now robustly solved in a matter of seconds.
- **Multi-phase optimal control:** The user can connect phases of arbitrary length with state jumps such as a sudden mass drop. A different collocation method may be used for the phases.
- **Scaling module:** PROPT has built-in capabilities for scaling advanced trajectory optimization problems. Many aerodynamic problems have control handles such as angles, but may work on very different levels for altitude and velocity. The software can automatically scale the problem to deal with such cases.
- **Source transformation:** The PROPT software is the first MATLAB module to enable complete source transformation for optimal control problem.
- **DAE formulation:** The PROPT software allows for a DAE formulation of the dynamic system. Other methods use an ODE formulation and path constraints. An ODE is a special case of a DAE, but PROPT accepts both formulations by default.
- **Arbitrary collocation points:** PROPT can use any set of collocation points, including, of course, Gauss and Chebyshev points.
- **One-page formulations:** Most optimal control problems are simply defined in one MATLAB m-file.
- **Parameter estimation:** Dynamic systems can be modeled and problem coefficients and expressions can be obtained.



Special Features

- ✓ Ability for end-user to generate highly optimized source code for further processing and modification.
- ✓ Treatment of non-smooth expressions such as min, max and abs.
- ✓ Usage of numerical differentiation or automatic differentiation for problems not supported by the source transformation package tomSym.

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Examples

The PROPT software includes a continuously expanding number of test cases and examples. The aim is to cover all applicable optimal control areas. Please refer to the [PROPT manual](#) for more information. The areas are:

- ✓ Aerodynamic trajectory optimal control
- ✓ Bang-bang control
- ✓ Chemical engineering
- ✓ Dynamic systems optimal control
- ✓ General optimal control
- ✓ Large-scale linear quadratic optimal control
- ✓ Multi-phase system optimal control
- ✓ Mechanical engineering optimal control
- ✓ Non-differentiable optimal control
- ✓ Parameter estimation for dynamic systems
- ✓ Singular optimal control

Van der Pol Oscillator

Minimize:

$$J_{x,t} = x_3(t_f)$$

Subject to:

$$\begin{cases} \frac{dx_1}{dt} = (1 - x_2^2) * x_1 - x_2 + u \\ \frac{dx_2}{dt} = x_1 \\ \frac{dx_3}{dt} = x_1^2 + x_2^2 + u^2 \\ x(t_0) = [0 \ 1 \ 0] \\ t_f = 5 \\ -0.3 \leq u \leq 1.0 \end{cases}$$

To solve the problem with PROPT the code to right can be used (with 60 collocation points):

```
toms t
p = tomPhase('p', t, 0, 5, 60);
setPhase(p);
tomStates x1 x2 x3
tomControls u

x0 = {icollocate({x1 == 0; x2 == 1; x3 == 0})
      collocate(u == -0.01)};

cbox = {-10 <= icollocate([x1;x2;x3]) <= 10
        -0.3 <= collocate(u) <= 1};

cbnd = initial({x1 == 0; x2 == 1; x3 == 0});

ceq = collocate({dot(x1) == (1-x2^2)*x1-x2+u
                dot(x2) == x1; dot(x3) == x1^2+x2^2+u^2});

objective = final(x3);
solution = ezsolve(objective, {cbox, cbnd, ceq}, x0);
```

