2018-00721 - Numerical optimization for frictional contact problems [PhD campaign]

Level of qualifications required : Graduate degree or equivalent
Fonction : PhD Position

About the research centre or Inria department

Inria the French national institute for research in computer science and control, is dedicated to fundamental and applied research in information and communication science and technology (ICST). Inria has a workforce of 3,800 people working throughout its eight research centers established in seven regions of France.

Grenoble is the capital city of the French Alpes. Combining the urban life-style of southern France with a unique mountain setting, it is ideally situated for outdoor activities. The Grenoble area is today an important centre of industry and science (second largest in France). Dedicated to an ambitious policy in the arts, the city is host to numerous cultural institutions. With 60,000 students (including 6,000 foreign students), Grenoble is the third largest student area in France.

Context

TRIPOP is a joint research team of Inria Grenoble Rhône-Alpes and of the Laboratoire Jean Kuntzmann and started in January 2018 as a follow up of the BIPOP team. The team is mainly concerned by the modeling, the simulation and the control of nonsmooth dynamical systems. Nonsmooth dynamics concerns the study of the time evolution of systems that are not smooth in the mathematical sense, i.e., systems that are characterized by a lack of differentiability, either of the mappings in their formulations, or of their solutions with respect to time. In mechanics, the main instances of nonsmooth dynamical systems are multibody systems with Signorini’s unilateral contact, set-valued (Coulomb-like) friction and impacts. In Electronics, the main instances are switched electrical circuits with ideal components (diodes, switches, transistors, ...)

Key-words : Nonsmooth dynamical systems, Contact, Friction, Numerical Methods, Optimization

Assignment

Interfaces with unilateral contact and friction are ubiquitous in multi-body mechanical systems. Let us cite for instance the linkages or mechanisms in robot applications, circuit-breakers and watch mechanisms, the granular materials or mechanical assembly with flexible solids. In these applications, an accurate modeling and an efficient simulation of frictional contact is mandatory.

It has been shown in [1,2,3] that the discrete problem can be naturally formulated as a nonlinear and nonsmooth second-order cone complementarity problem (SOCP).

If the nonlinear part of the problem is neglected, the problem is an associated friction problem with dilatation, and by the way, is a gentle SOCLCP with a positive matrix. When the non-associated character of the friction is taken into account, the problem is non-monotone and nonsmooth, and then very hard to solve efficiently.

This generic problem is at the heart of most of the simulation techniques of mechanical systems with 3D Coulomb’s friction and unilateral constraints. as discussed in [4], it might be the result of a time–discretization scheme by event–capturing time–stepping methods or event–detecting (event–driven) techniques of dynamical systems or a space–discretization (by FEM for instance) of the quasi-static problems of frictional contact mechanics.

This problem is a difficult problem for which there is no universal numerical to solve it in an efficient and robust way. A quite exhaustive comparison of numerical techniques has been done in [5]. On one hand, we show that algorithms based on Newton methods for nonsmooth equations solve quickly the problem when they succeed, but
suffer from robustness issues mainly when the matrix $H$ has not full rank. On the other hand, the iterative methods dedicated to solving variational inequalities are quite robust but with an extremely slow rate of convergence. To sum up, as far as we know there is no option that combines time efficiency and robustness.

Main activities

In this PhD thesis, the goal is to take benefit from robust algorithms from the optimization community and to adapt them to the discrete frictional contact problem in order to solve the problem of robustness.

Let us list the possible stages of the thesis

- Bibliography study and equivalent formulation of the SOCP: optimization formulation, Lagrangian duality, first order optimality conditions,
  - By introducing slack variables, it is possible to relax the problem in order to obtain a convex optimization problem. One of the goal of the thesis is to study this relaxation in terms of:
    - a) equivalence with the original problem and
    - b) existence and uniqueness of solution. Once theses relaxations will be studied, the objective is to select a good relaxed formulation prone to numerical algorithms.

- Another difficulty of this problem is related to the redundancy of the cone constraints that is usual when large-scale applications are considered. Another goal of the thesis is to study the possibility of regularization through a proximal point technique. The goal is to design an algorithm and to test it on a large collection of problems.

- Finally, a last step would consist to study and apply accelerated first-order methods like alternating direction method of multipliers (ADMM)

Skills

Applied mathematics and/or computational mechanics

Benefits package

- Subsidised catering service
- Partially-reimbursed public transport
- Social security
- Paid leave
- Flexible working hours
- Sports facilities

Remuneration


Monthly salary after taxes : around 1596,05€ for 1st and 2nd year. 1678,99€ for 3rd year. (medical insurance included).