Rheonomic frictional contacts for simulating drifting in conveyors and feeders

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Abstract. Within the context of non-smooth dynamics, we propose a new class of contact constraints that simulates the drifting of parts when in contact with conveyor belts, vibratory feeders or similar devices for transportation of parts. In the proposed formulation, contacts are handled as rigid contacts between parts and a stationary object, where a time-dependant term is added to the complementarity constraint in order to enforce the tangential motion of the parts. The needed parameters are quite simple, being limited to the friction coefficient and to a map of drifting speeds on the contact surface.

Introduction

Conveyor belts, vibratory feeders and similar devices are widely used in engineering applications, for example in the food industry, in granular material processing and in bulk material transportation. In general all these devices share a common issue when one needs to simulate them: the desired effect -namely, the drifting of parts over conveying surfaces- is a simple phenomena, yet the simulation requires complex models and/or short time steps (for instance the realistic simulation of a conveyor belt would require the simulation of large deformations of a rubber belt, etc.) To bypass the difficuty of modeling the transportation system, we propose a surrogate model based on non-smooth dynamics [1].

Method

In our approach, we use just static conveying surfaces, but at the same time the set-valued force laws for frictional contacts are extended to include a rheonomic term $\boldsymbol{C}_t = \{C_{t_u}, C_{t_v}\} \in \mathbb{R}^2$ where $(u, v, t) \mapsto \boldsymbol{C}_t$ is a user-defined function on the surface manifold, representing the required tangential drifting speed. Such speed map can be obtained from experiments, from numerical models or simply from analytical expressions: for example a linear conveyor belt of constant speed s would simply have $\boldsymbol{C}_t = \{s, 0\}$. Given a set $\mathcal{G}_\mathcal{A}$ of contact points, we express each contact law at the i-th contact point as a rheonomic cone complementarity:

$$\widehat{\gamma}_i \in \Upsilon_{\mathcal{A},i} \perp \bar{\boldsymbol{u}}_i \in \Upsilon^*_{\mathcal{A},i}, \quad \forall i \in \{\mathcal{G}_\mathcal{A} | \Phi_i = 0\} \tag{1}$$

where $\Upsilon_{\mathcal{A},i}$ is the second order Lorentz friction cone, $\Upsilon^*_{\mathcal{A},i}$ is its dual, Φ_i is the contact gap, $\widehat{\gamma}_i$ is the reaction impulse, $\boldsymbol{u}_i$ is the contact relative velocity, $\mathbf{v}_{\|,i}$ is the tangent velocity, μ_i is the friction coefficient, and

$$\bar{\boldsymbol{u}}_i = \left\{ \begin{array}{l} u_{n,i} + \mu_i \left\| \mathbf{v}_{\|,i} \right\| \\ u_{u,i} + C_{t_u}(u, v, t) \\ u_{v,i} + C_{t_v}(u, v, t) \end{array} \right\} \tag{2}$$

By doing this, we inherit the high performance and stability of the non-smooth formulation [2], at the same time allowing large time steps in the simulation of transportation phenomena. Other effects such as friction limits in sticking or sliding, or collision restitution, are preserved.

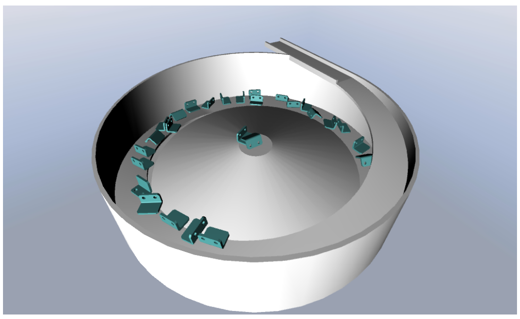

Figure 1: Simulation of a bowl feeder. The proposed method allows large time steps ($h = 0.01$s in this case).

References

[1] Acary, V., Brogliato, B. (2008) Numerical methods for nonsmooth dynamical systems: applications in mechanics and electronics. Springer, DE.

[2] Tasora, A., Mangoni, D., Benatti, S., Garziera, R. (2021) Solving variational inequalities and cone complementarity problems in nonsmooth dynamics using the alternating direction method of multipliers. *Int J Numer Methods Eng* **122**:4093-4113.