Dynamic balancing of mechanisms

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A mechanism is said to be statically balanced if, for any motion, there is no reaction force on the base, excluding gravity. It is dynamically balanced if there is no reaction force and torque on the base. Statically and dynamically balanced mechanisms are highly desirable for many engineering applications in order to reduce fatigue, vibrations and wear. Static and dynamic balancing can also be used in applications such as, for instance, the design of more efficient flight simulators or the design of compensation mechanisms for telescopes. Additionally, dynamic balancing is very attractive for space applications since the reaction forces and torques induced at the base of space manipulators or mechanisms are one of the reasons why the latter are constrained to move very slowly.

The static balancing problem was first addressed by Berkof and Lowen [1], who provided conditions for the planar four-bar mechanism in terms of the design parameters when the geometric parameters are sufficiently generic. A non-generic solution was then found in [2]. Although families of solutions for the dynamic balancing were presented in the literature, for example in [3], no complete overview was given.

Using symbolic computation, we introduce a new approach to completely chararacterise such mechanisms. First, we derive a system of algebraic equa-

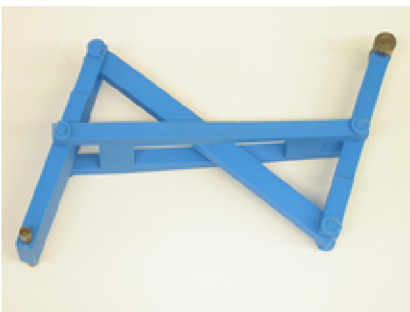

Figure 1: Dynamically balanced planar four-bar mechanism (Gabriel's Mechanism, [5])

tions in the design parameters and the angles in configuration space, modelled by complex variables. We want to take optimal advantage of the Newton polygons of the equations, and so we use a well-known theorem of Ostrowski and a toric variant of polynomial division to eliminate the complex variables. Then, we introduce special static and dynamic design parameters for which the equations become linear. Using this method, necessary and sufficient conditions between the design parameters for statically and dynamically balanced planar four-bar mechanisms are obtained. We also show how this method can be used to dynamically balance more complex mechanisms. More details can be found in [4, 5].

[1] R.S. Berkof and G. G. Lowen, 1969. A new method for completely force balancing simple linkage. Journal of Engineering for Industry, pp. 21–26.
[2] C.M. Gosselin, 1997. Note sur l'équilibrage de Berkof et Lowen. In Canadian Congress of Applied Mechanics(CANCAM 97), pp. 497–498.
[3] C.M. Gosselin, F. Vollmer, G. Côté, Y. Wu, 2004. Synthesis and design of reactionless three-degree-of-freedom parallel mechanisms. IEEE Transactions on Robotics and Automation.
[4] B. Moore, J. Schicho, C.M. Gosselin, 2007. Dynamic balancing of planar mechanisms using toric geometry. Technical Report 2007-28, SFB F013, arXiv:0711.3742.
[5] http://robot.gmc.ulaval.ca/en/research/theme106.html