Educational and Research Kinematic Capabilities of GIM Software

Erik Macho, Victor Petuya, Mónica Urízar, Mikel Diez and Alfonso Hernández

Abstract In this paper an educational and research software named GIM is presented. This software has been developed with the aim of approaching the difficulties students usually encounter when facing up to kinematic analysis of mechanisms. A deep understanding of the kinematic analysis is necessary to go a step further into design and synthesis of mechanisms. In order to support and complement the theoretical lectures, GIM software is used during the practical exercises, serving as an educational complementary tool reinforcing the knowledge acquired by the students.

Keywords Motion simulation · Computational kinematics · Mechanism synthesis · General purpose software

1 Introduction

In the teaching of subjects related to Machine Theory, supporting and complementing theoretical lectures with a simulation and analysis software, helps the students to understand deeply and visually the theoretical bases of the Mechanisms

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Science. In the Department of Mechanical Engineering of the University of the Basque Country (UPV/EHU) two main Bachelor subjects can be highlighted in this field: Applied Mechanics [1, 2] and Kinematics of Mechanisms [3]. In these subjects, GIM software is used.

GIM is a registered software created by the COMPMECH Research Group (www.ehu.es/compmech). The software has been developed focusing, not only on educational purposes but also on research in the field of computational kinematics and mechanism design applications. The software presented in this article also has potential to be used by students of Master Degrees in Mechanical Engineering and other subjects related to Robotics, Mechanism Design, etc.

GIM has been developed in a modular structure. After defining the kinematic structure of a linkage in the Geometry module, the user can perform the motion simulation in the Motion module. GIM is mainly oriented to the field of kinematic analysis, motion simulation and dimensional synthesis of planar mechanisms. In any case, it also includes other modules for workspace and singularity evaluation [4] and static analysis of mechanical structures.

Currently other Universities are using different kinematic softwares during their lessons. In RWTH Aachen, IGM students use the interactive geometry software Cinderella (freeware tool provided by Springer) during mechanism lectures [5]. Other Spanish Universities use well known commercial softwares as GeoGebra [6] or ADAMS [7]. In this paper, we will present the main GIM capabilities used mainly by Bachelor and Master student but also by some of our PhD students.

2 Kinematic Analysis

In this section are presented and briefly described the main capabilities of the so-called *Motion* module. This module is able to simulate the motion of any n-dof planar mechanism with any kind of revolute and prismatic joints. Also the disk-disk and disk-line rolling and cam contacts can be modelled.

2.1 Position, Velocity and Acceleration Problems

Figure 1 shows an example of the most elemental results that can be depicted when the motion of a mechanism is obtained and simulated. Obviously, once the geometry has been defined, the first step to compute the motion is to define as many actuators in the mechanism as degrees of freedom. There are different types of actuators, i.e. rotary ones, linear ones, as well as several input function types, i.e. polynomial or sinusoidal, available to control the position, velocity and acceleration of each actuator.

The trajectories, velocities (v) and accelerations (a) of any point, and the angular velocities (ω) and accelerations (α) of all elements can be drawn. Also the center of

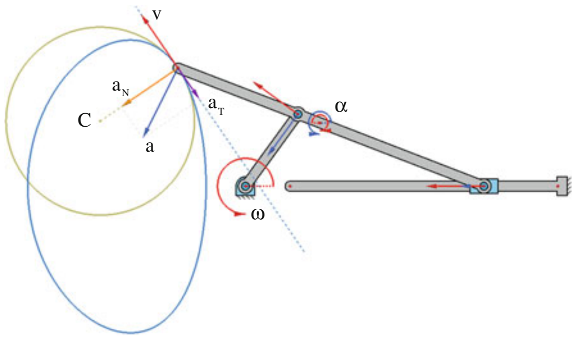

Fig. 1 General motion simulation results

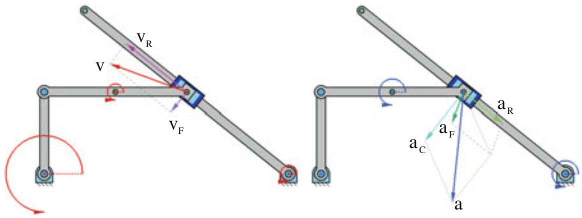

Fig. 2 Relative motion composition in velocities and accelerations

curvature (C) of the trajectory and the intrinsic components of the acceleration (a_T, a_N) can be represented. From an academic point of view, the compliance of all the well-known properties of these magnitudes can be directly observed and understood along the whole motion, e.g. the velocity is always tangent to the trajectory, or the normal acceleration points always towards center of curvature.

All motion results can be obtained not only in the fixed frame, but also with respect to any relative reference. Such a capability, as shown in Fig. 2, provides the best support for explaining (or understanding) the frame (v_F, a_F) and relative (v_R, a_R) motion compositions (a_C is Coriolis term).

In the same way, the user can check how the specific properties of the rolling motion, with or without sliding, are verified, e.g., as shown in Fig. 3, when a rolling motion with no sliding component is performed, contact points in both elements have the same velocity and the same projection of the acceleration over the contact tangent line. Those properties are not satisfied when exist sliding in the rolling.

2.2 Kinematic Geometry

GIM software is able to compute and represent the main kinematic geometrical entities of any element of the mechanism, such as the instantaneous center of rotation (P), the pole of accelerations (Q), the fixed and moving centrodes (c.f. and

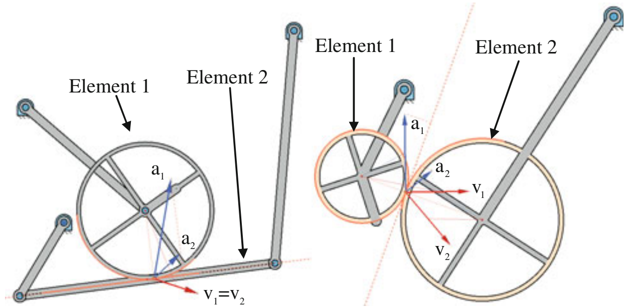

Fig. 3 Velocities and accelerations of contact points in a pure rolling and in a cam joint

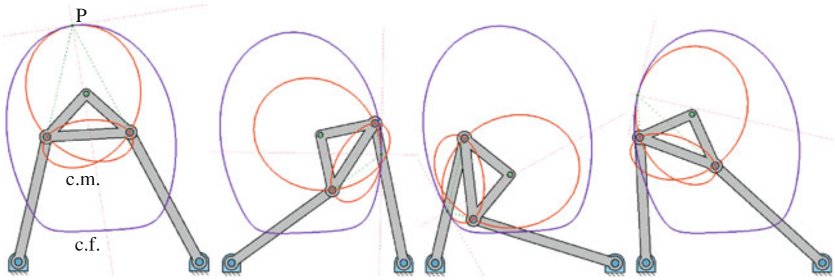

Fig. 4 Rolling motion sequence between the fixed and moving centrodes

c.m.) and the inflection and Bresse circles (c.i. and c.b.). When studying these entities, students have an interactive tool at hand which facilitates a deeper understanding.

For example, as shown in Fig. 4, during the motion simulation, it is checked that the fixed and moving centrodes are always tangent at the instantaneous center of rotation, and the moving centrode moves welded the element, rolling over the fixed one. In the same way, as this tool enables to drag the coupler point of an element to any position in the moving plane, it can be observed that the pole of velocity has acceleration and the pole of acceleration has velocity (Fig. 5, up). Also, any point on the inflection circle is passing through an inflection point on its trajectory and lacks of normal acceleration, as well as any point on the Bresse circle lacks of tangent acceleration (Fig. 5, down).

2.3 Advanced Computations

Apart from the basic kinematic geometry, some advances features can be issued. Here are found some examples. Figure 6 shows the envelope of a line that moves fixed to the coupler element of a mechanism. As it is known, in positions where

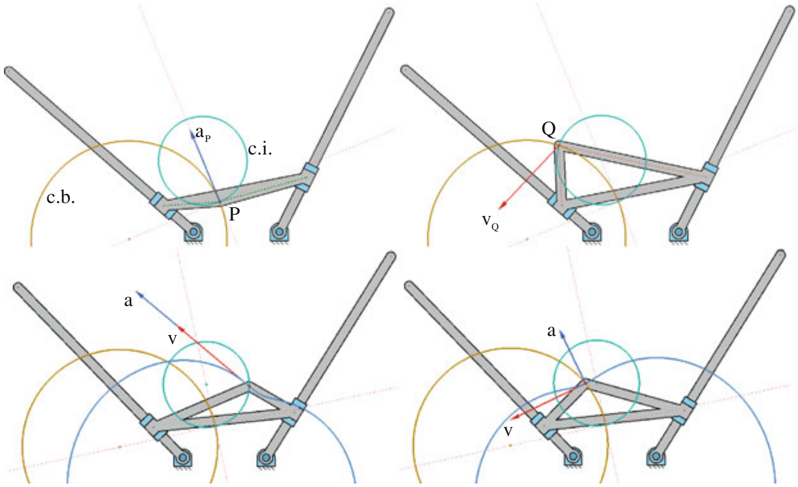

Fig. 5 Instantaneous centers of rotation and acceleration and inflection and Bresse circles

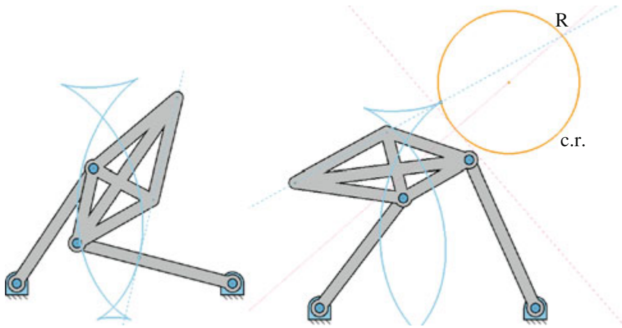

Fig. 6 Moving line envelope and return circle

such a line passes through the return pole (R), the envelope curve has a cusp point (c.r. is the return circle).

For some simple mechanisms, as the 4-bar linkage, the cubic of stationary curvature (c.s.c.) and the pivot point curve (p.p.c.) can be traced. When the coupler point is located at the intersection between the cubic of stationary curvature and the inflection circle (Ball point, B) it is achieved a quasi-straight-line trajectory in the proximity of such a point (Fig. 7).

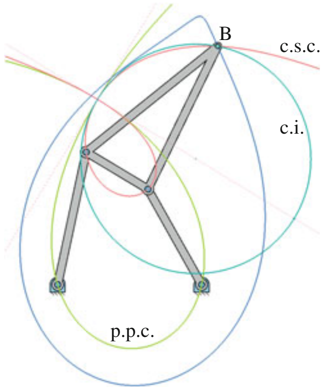

Fig. 7 Cubic of stationary curvature, pivot point curve and ball point

3 Dimensional Synthesis

The Motion module presented in the previous section has a general purpose and can solve a large amount of planar mechanisms. Apart from this module, the program provides another one that deals with the dimensional synthesis of one specific mechanism, the four-bar linkage. Three traditional synthesis problem types have been addressed, i.e. path generation, rigid body guiding and function generation.

3.1 Path Generation Synthesis

This synthesis is based on the use of precision points and consists in determining a mechanism whose coupler point trajectory passes exactly through some specific positions. With this software tool, the user can drag the precision points to change their position and the computation of the mechanism that fulfills all conditions is done in real time. This non-linear problem admits many different solutions for the same input values. The designer has the full control to visualize each of them, as depicted in Fig. 8.

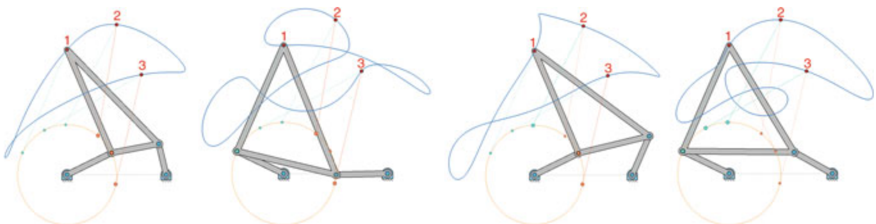

Fig. 8 Synthesis with three precision points. Different solutions for the same data

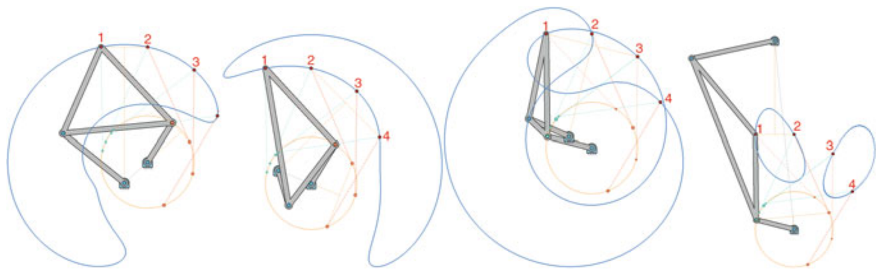

Fig. 9 Synthesis with four precision points. Order error and loop error

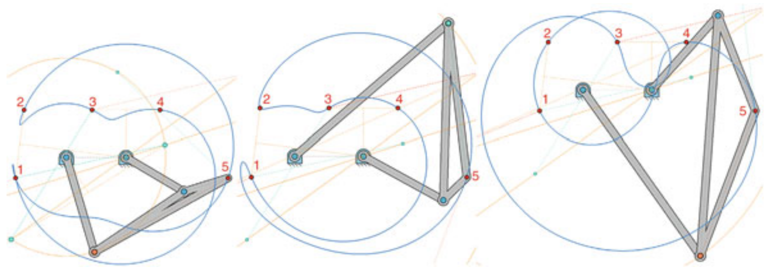

Fig. 10 Synthesis with five precision points. Different solutions for the same data

The program offers the option for making the mechanism synthesis being defined three, four, or five precision points of the trajectory. This ability is shown in Figs. 8, 9 and 10. From the academic point of view, one of main advantages is the possibility of checking that some solutions do not accomplish the right order in the sequence of precision points, order error, and also, in the case of Grashof's four bar linkages, could appear the so-called branch error, that means that some points belong to the disconnected path corresponding to the crossed quadrilateral.

Also, the software allows the visualization of the classical geometrical constructions for making the synthesis. User can choose between displaying or not such auxiliary constructions. This feature is valuable for an academic purpose.

3.2 Rigid Body Guiding

The solid element guiding synthesis computes the mechanism that is able to fully locate an element in a set of desired postures (position and orientation). Figure 11 shows the three alternatives given in the program. The first one allows the user to specify three postures and the relative positions of the floating joints (the shape of the coupler). Using the second option, apart from three desired postures, positions of fixed joints can be specified. Finally, solid element guiding for four target postures can be done.

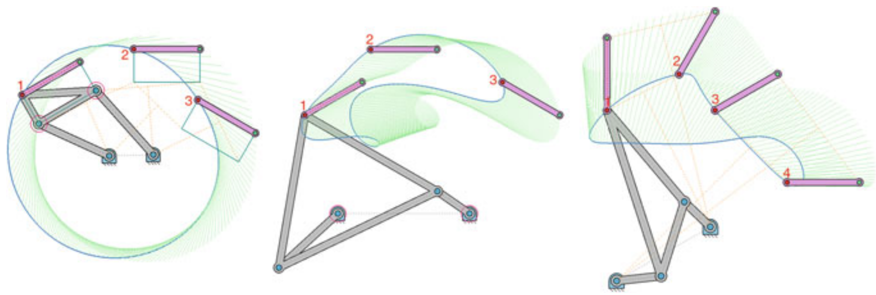

Fig. 11 Synthesis for solid element guiding

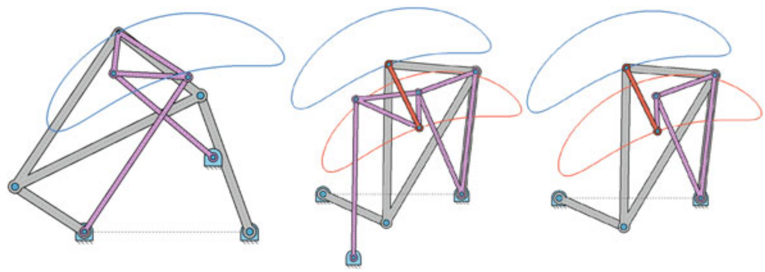

Fig. 12 Four-bar mechanism cognate and translational mechanisms

3.3 Additional Functionalities

In the Synthesis module the user can find some extra features related with the design alternatives based in the four-bar linkage. Some of them are presented in Fig. 12. Apart from the crossed mechanism, cognates, which trace the same coupler trajectory, are obtained. Based on them, the so-called 1-dof translational mechanisms are obtained. The two known versions can be represented: the redundant one and the non-redundant one.

4 Conclusions

The software presented in this paper allows students and researchers to model and analyse in a quick and simple way n-dof planar linkages. Using the software capabilities, the user is able to carry out a deep kinematic performance analysis of the whole mechanism. GIM software has proven to be a very effective tool to complement and reinforce the theoretical concepts explained during the lectures of subject related to Mechanism and Machine Science.

GIM software can be freely downloaded from the COMPMECH web site in the following link: www.ehu.es/compmech/software.

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