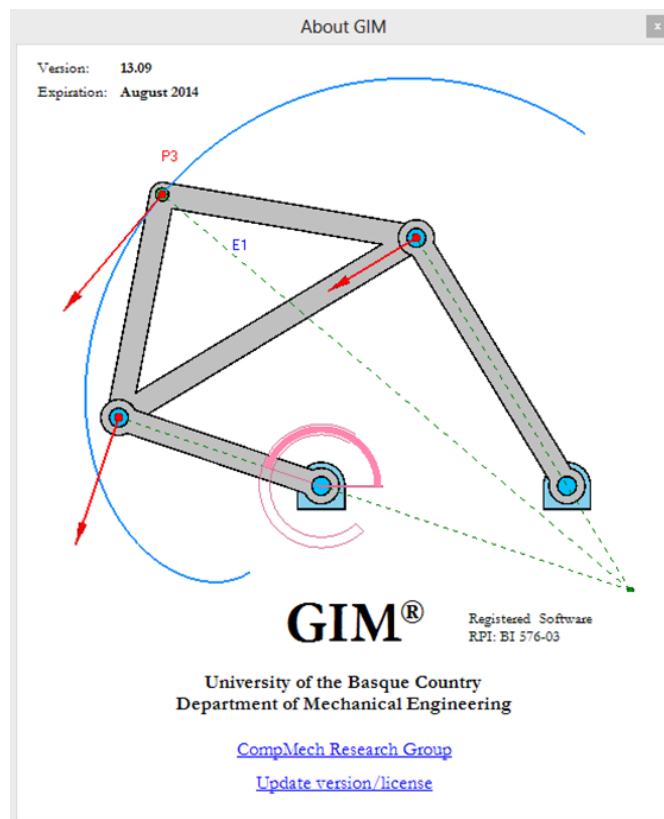


# Tutorial of GIM Software

## Part I: Kinematic Analysis

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# 1 What is GIM?

GIM is a registered software created by the COMPMECH Research Group, belonging to the Department of Mechanical Engineering of the University of the Basque Country (UPV/EHU). The software is intended for educational purposes, in particular destined to the field of kinematic analysis, motion simulation and synthesis of planar mechanisms, and also static analysis of mechanical structures.

This tutorial refers to GIM Software, Part I, which focuses on the kinematic analysis and motion simulation of mechanisms. Planar mechanisms with  $n$ -ary elements joined by revolute and prismatic pairs can be introduced. The position problem is solved iteratively using a numerical method, several of its conditions can be controlled and visualized. Inputs can be defined with a polynomial up to the quintic, so position, velocity and acceleration can be specified at motion extremes.

The program allows plotting the paths of points of interest, as well as the curvature center and curvature center locus of the trajectory, and also the area swept by specific elements of the mechanism can be depicted. Velocities and accelerations can be obtained and the corresponding vectors visualized as the motion is performed, also graphs and tables associated with this data can be plotted. Every kinematic construction can be represented: Instantaneous Center of Rotation (ICR), fixed and moving polodes, acceleration pole, main circles (inflection circle, return circle and Bresse circle), and so on (see illustrative example in Fig. 1).

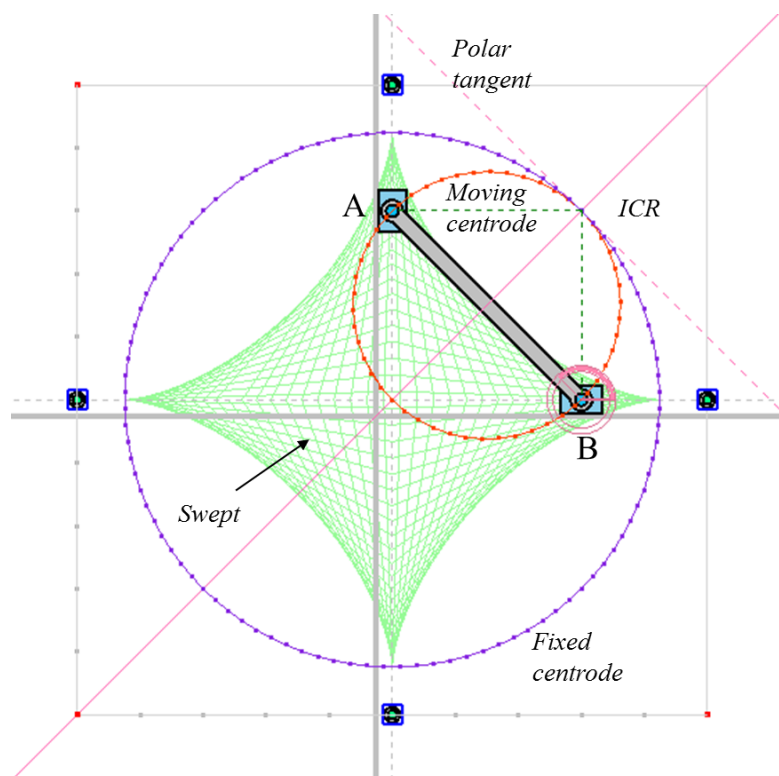


Figure 1: Illustrative example: PRRP mechanism

## 1.1 Application of GIM software

This software has been developed by COMPMECH Research Group 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.

## 1.2 Access to GIM software

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

## 2 Main Modules in Kinematic Analysis

Regarding the kinematic analysis of planar mechanisms, GIM software has two main modules: **Geometry** and **Motion**.

- Geometry module is the one in charge of defining a specific design of the mechanism object of study.
- Motion module performs the kinematic analysis and motion simulation of the mechanism.

### 2.1 Geometry module

In Fig. 2, the starting main window associated with Geometry module is shown. In the following sections, the different options included in this module are explained in detail.

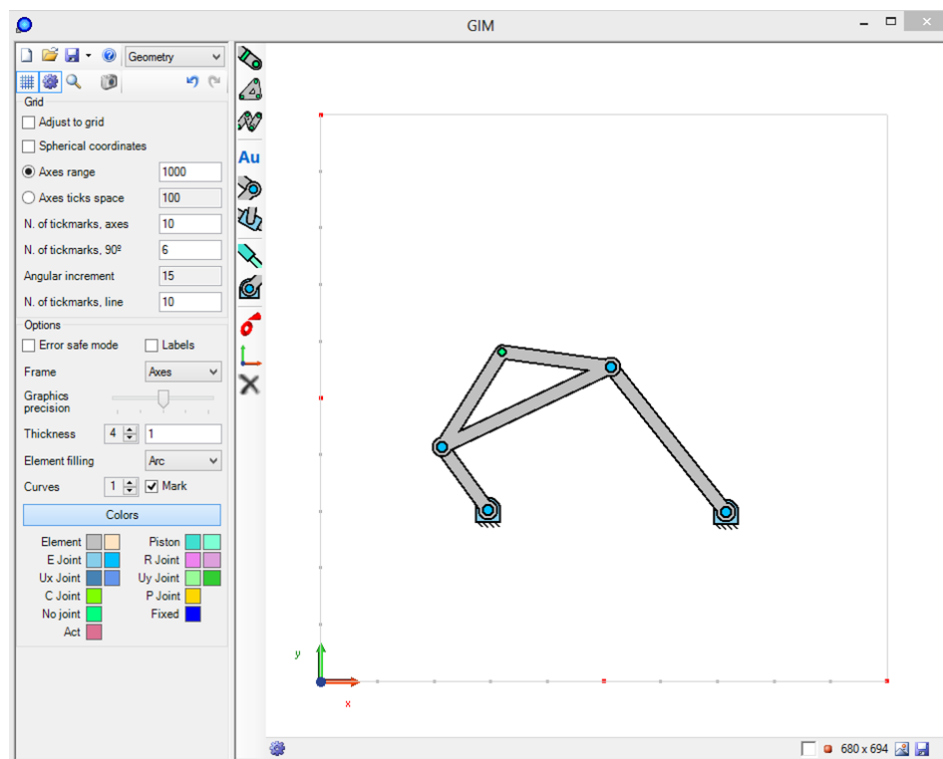


Figure 2: Main window of Geometry module

#### 2.1.1 Basic options

On the left-hand side of the main window several options appear. The icons located at the upper left-hand corner serve to perform common actions, such as creating a new document, open an existing document or saving the work. Just below, a second bar contains some other icons which display two specific menus, as shown in Fig. 3.

The first one, *Grid* menu (see Fig. 3 left), has the following options:

- *Adjust to grid*: selecting this option enables the designer to locate the nodes of the mechanism adjusting to the grid depicted in the plotting window.
- *Spherical coordinates*: serves to define the design of the mechanism using spherical coordinates.
- *Axes range*: permits defining a specific range for the grid axes.
- *Axes ticks space*: serves to define the number of tickmarks appearing in the grid.

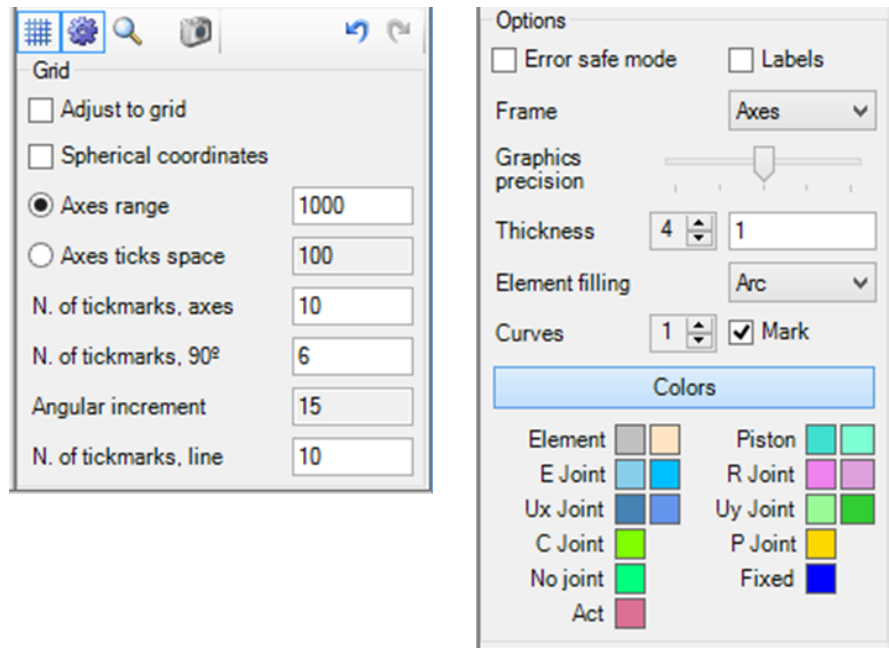


Figure 3: *Grid* and *Options* menus of Geometry module

The second menu, *Options* menu, (see Fig. 3 right), adds the following possibilities:

- *Error safe mode*: it avoids closing the program if some error occurs.
- *Labels*: selecting this option enables displaying the labels of each node, element and joint of the mechanism.
- *Frame*: it includes four possibilities. The default one, *Axes*, displays the two principal axes XY of the grid. The other options are: *None*, no grid is shown; *Ground*, full-grid, and *Walls*, similar to *Ground* but depicts the grid of all drawing planes.
- *Graphics precision*: it permits modifying the precision of the graphics displayed.
- *Thickness factor*: it permits modifying the thickness of the elements.
- *Element filling*: related to the filling mode of the elements.
- *Colors*: it shows the color legend of each elements and joint type.

### 2.1.2 Defining the geometry of the mechanism

In this section, it is explained how to define a specific design of a mechanism under study. To do so, the designer will use the icons included in the vertical bar on the left-hand side of the drawing screen. As shown in Fig. 4, these icons serve for: creating the nodes of the mechanism, creating the elements, defining the type of joints (revolute or prismatic joints can be established), establish the fixed joints, modifying or deleting elements, etc.



Figure 4: Icons included in Geometry module to design a mechanism

The process to depict the mechanism is very simple: select the desired icon and locate the cursor mouse on the drawing screen. In general, the basic design process consists in: *first*, create the nodes of the mechanism; *second*, define the elements between the established nodes and *finally*, define all the joint types.

- **Nodes:** To create the nodes just select the corresponding icon, and then, having the mouse cursor on the drawing screen, just click on the desired location. Note that it is also possible to define specific  $(x,y)$  coordinates of the node by writing the numerical values on the boxes that appear at lower left-hand corner once the *nodes* icon has been selected.
- **Elements:** Once the nodes have been depicted, the elements can be created. To do so, select the *elements* icon, and again move the mouse cursor to the drawing screen. Click once on the first node forming the element, and click **twice** on the last node of the element.

- **Kinematic joints:** To define the kinematic joints of the mechanism just select the corresponding icon (revolute or prismatic joint icon) and go to the drawing screen in order to click on the corresponding node.

In order to illustrate the designing process, several examples are shown in the following videos:

- Video of **Four-bar mechanism** - creating the geometry:  
<http://www.ehu.es/compmech/software/gim-examples-4-bar-mechanism/>
- Video of **PRRP mechanism** - creating the geometry:  
<http://www.ehu.es/compmech/software/gim-examples-prrp-mechanism/>

## 2.2 Motion module

Motion module is the module in charge of carrying out the motion simulation and kinematic analysis of the planar mechanism under study. The user can access this module only once the geometry of the mechanism has been completely defined in Geometry module. To get into Motion module, just select the option *Motion* from the display menu on the upper bar of the main window.

In Fig. 5, the starting main window associated with Motion module is shown, using the four-bar mechanism as an illustrative example.

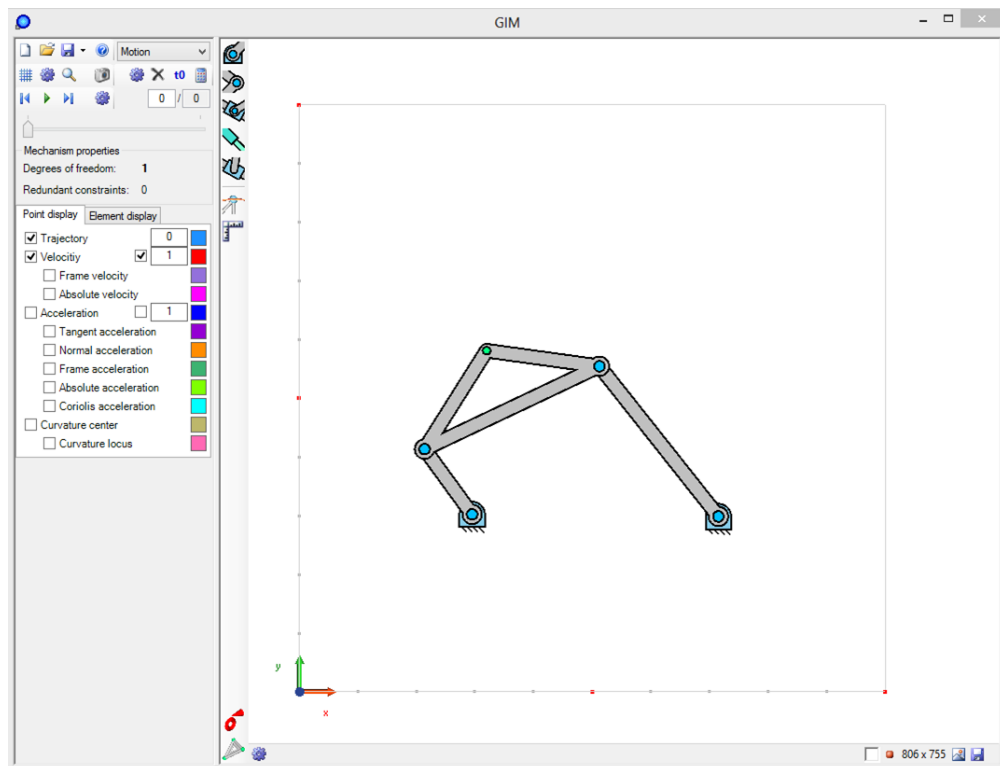


Figure 5: Main window of Motion module

This screen contains three main parts:



1. The vertical bar close to the drawing screen in which several icons appear so as to define the inputs' motion. The first five icons serve to define the inputs of the mechanism. The two last icons permit selecting specific elements or nodes, and showing graphs respectively (see Fig. 6).

The way the input conditions has to be established is detailed in Section 2.2.1.

2. The top horizontal bar containing, on the one hand, the icon that serves to compute the motion (the *calculator* icon) and, on the other hand, the controls of the motion simulation (play/pause, next step, previous step). Besides, just below the motion controls, it is displayed the number of degrees of freedom, and the number of redundant constraints (see Fig. 7).
3. Two boxes named **Point display** and **Element display**, in which the kinematic properties related to points or elements of the mechanism are shown. This is the main part of the Motion module, as it contains all the options that can be visualized in relation to important kinematic features of the mechanism, as for example, velocities and accelerations, points' trajectory, Instantaneous Center of Rotation (ICR), fixed and moving polodes, main circles, and so on (see Fig. 8).

Detailed explanation of the operation of this part is given in Section 2.2.2.

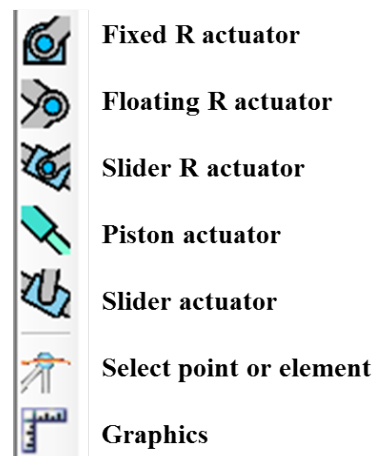


Figure 6: Vertical bar of Motion module

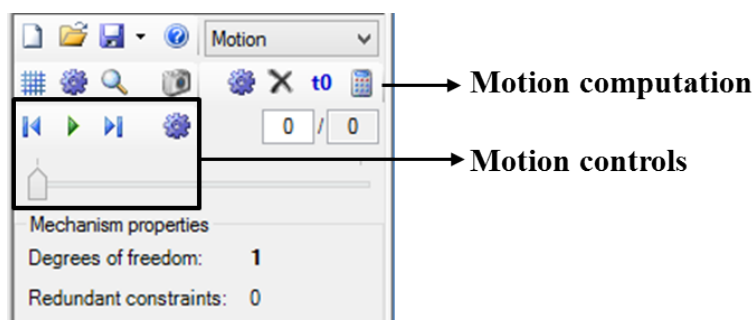


Figure 7: Motion controls of Motion module

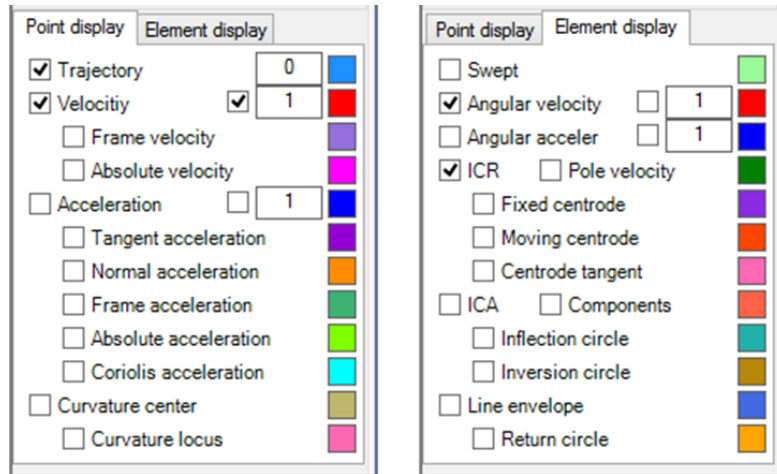


Figure 8: Kinematic properties included in Motion module

### 2.2.1 Defining the input conditions

The first step to proceed with the kinematic analysis of a mechanism under study is to define the input(s) of the mechanism. For a  $n$ -DOF mechanism,  $n$  number of inputs must be established. As highlighted in Fig. 6, the icons in the vertical bar serve to define the following type of inputs: fixed revolute actuator, floating revolute actuator, slider revolute actuator, piston actuator and slider actuator.

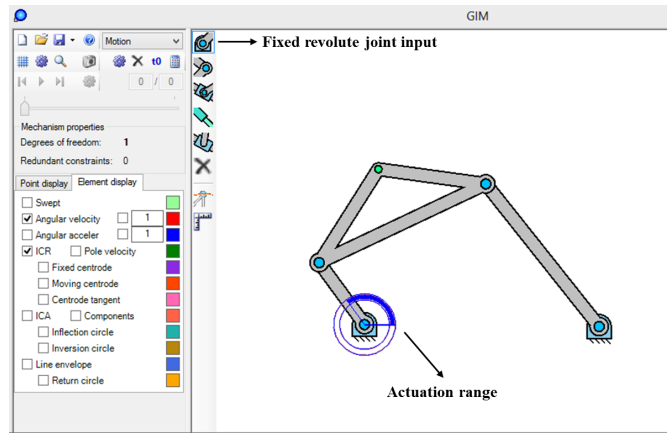
Following with the four-bar example, let us chose one of the fixed revolute joints as the actuated one, as shown in Fig. 9a. The process is very simple, first select any of the icons of the vertical bar associated with the input you want to specify, and then click on the corresponding input joint of the mechanism. Next, define the characteristics of the input (position, velocity, acceleration) by establishing the desired parameters on the right-hand side box menu, as shown in Fig. 9b.

The default input option consists in a linear increment of position, that is, constant velocity. However, the characteristics of the input actuation can be varied by the user, by modifying the parameters of position, velocity and acceleration displayed in the menu of Fig. 9b. A polynomial up to the quintic can be specified. The graphs on the right-hand side are displayed according to the established input conditions.

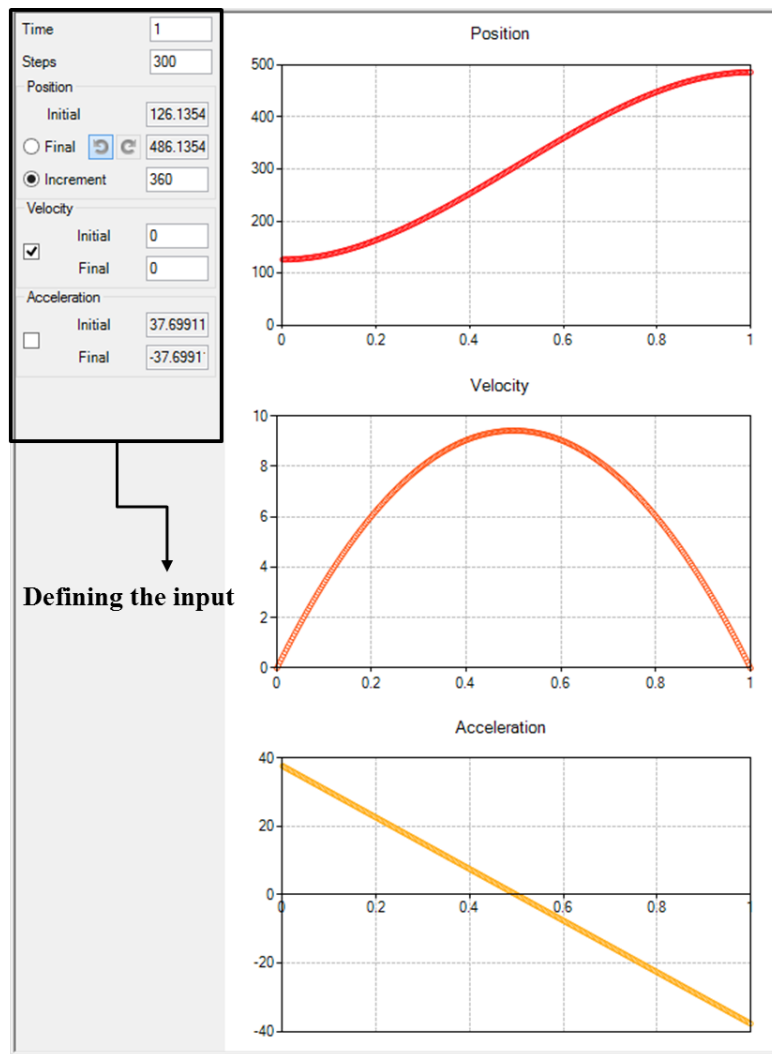
### 2.2.2 Getting into the kinematics

Once the input (or inputs in the case of more than one DoF) of the mechanism has been defined and the motion has been computed, the user is ready to analyze several kinematic properties of the mechanism.

As stated in Section 2.2, in particular focusing on the options of Fig. 8, there exist two menus regarding the kinematic properties that can be obtained. On the one hand, in relation to **points** of interest of the mechanism (**Point display** menu), the following data can be displayed:



(a)



(b)

Figure 9: Defining the input actuation: (a) selecting the input; (b) Establishing the input conditions

- Trajectory
- Velocity
  - Frame velocity
  - Absolute velocity
- Acceleration
  - Tangent acceleration
  - Normal acceleration
  - Frame acceleration
  - Absolute acceleration
  - Coriolis acceleration
- Curvature center
  - Curvature locus

On the other hand, regarding the **elements** of the mechanism (**Element display** menu), the user can obtain the nest features:

- Swept
- Angular velocity
- Angular acceleration
- ICR (Instantaneous Center of Rotation)
  - Pole velocity
  - Fixed centrode
  - Moving centrode
  - Centrode tangent
- ICA (Instantaneous Center of Acceleration)
  - Components
  - Inflection circle
  - Inversion circle
- Line envelope
  - Return circle

In order to visualize any of the aforementioned options (or various options simultaneously) it is just needed to click the box (or boxes) associated with the desired option included in *Point* or *Element* menu, and then select the point or element of interest.

An illustrative example is shown in Figs. 10 and 11. In Fig. 10, some properties of a point of interest, in this case the coupler point **P**, are displayed: the velocity and acceleration, its trajectory and the curvature center of the trajectory. Figure 11 displays significant kinematic features associated with a specific element, in this case the moving platform: the ICR, and the fixed and moving centrodes.

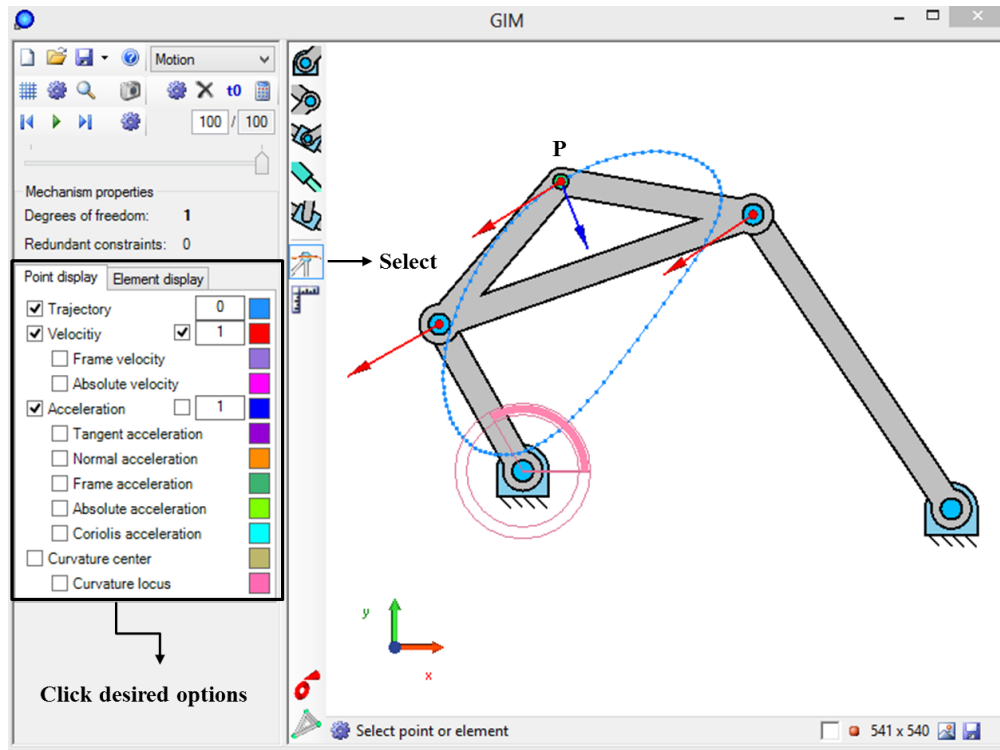


Figure 10: Showing kinematic properties of the coupler point

It is essential to *remark* that all of the kinematic features can be visualized not only for a certain position but all along the motion of the mechanism. In order to get this, just press the play button included in the motion controls.

Again, following with the four-bar example, the visualization of several features along the motion is shown in the following video:

- Video of **Four-bar mechanism** - properties related to points of interest and elements:  
<http://www.ehu.es/compmech/software/gim-examples-4-bar-mechanism/>

### 2.2.3 Graphical plots

Motion module allows to represent the graphs of features associated with points or elements. These graphics are obtained by selecting the icon indicated in Fig. 12, which displays the menu also shown in the figure. This menu is divided into the characteristics of points and the ones associated with elements.

With respect to points, the following graphs can be obtained:

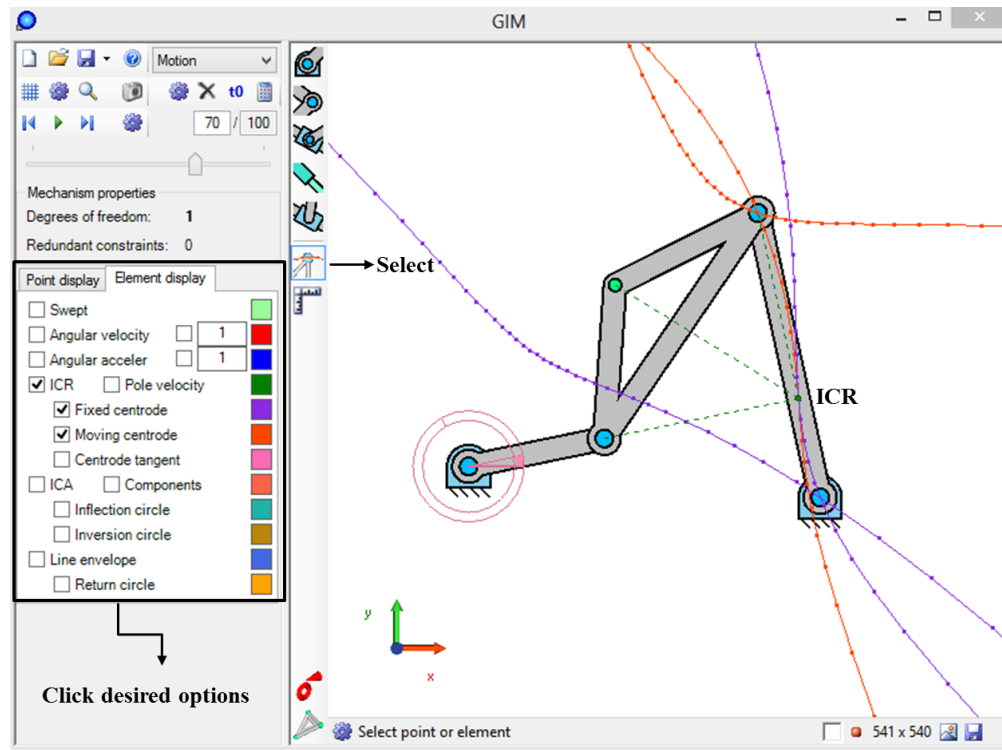


Figure 11: Showing kinematic properties of the moving platform

- Coordinates
- Velocity
- Acceleration
- Tangential acceleration
- Normal acceleration
- Curvature Center
- Curvature radius

And regarding the elements:

- Angular velocity
- Angular acceleration
- ICR
- Pole velocity
- IC of acceleration

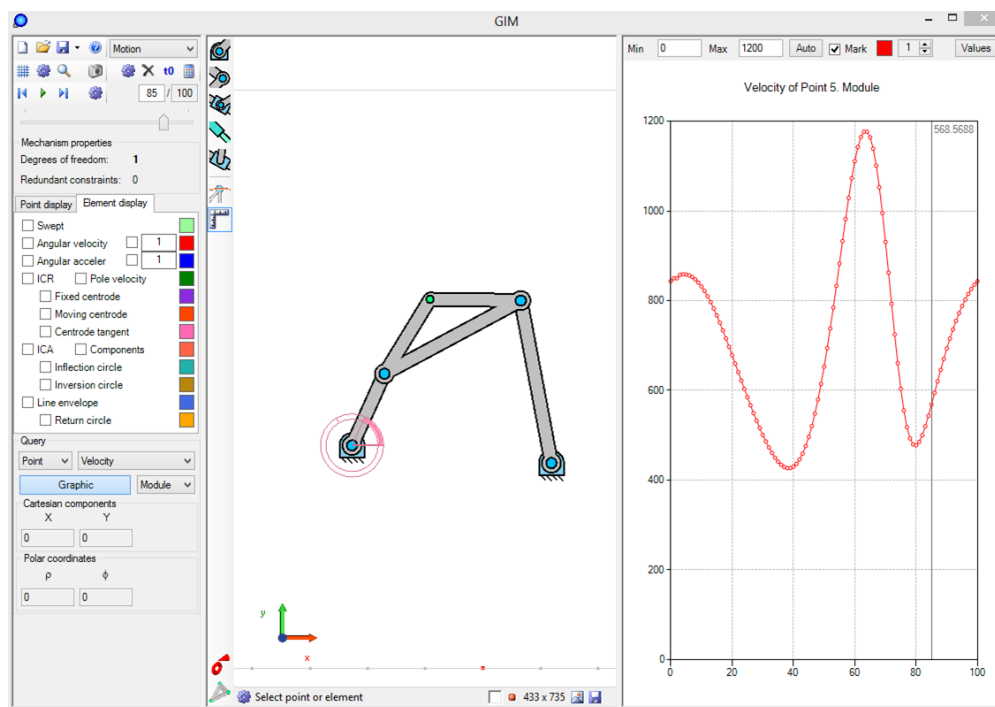


Figure 12: Obtaining graphs of features associated with points or elements

### 3 Examples of Planar Mechanisms

The analysis of different planar mechanisms (four-bar mechanism, 5R mechanism, Scotch Yoke mechanism, 3-RPR mechanism, etc) making use of GIM software is reported in the videos available in the subsequent link:

<http://www.ehu.es/compmech/software/>

Besides, several interactive video tutorials can be shown in:

<http://www.ehu.es/compmech/gim-software-tutorial/>

The video tutorials explain step-by-step how to create the geometry, carry out the motion simulation and perform the kinematic analysis of various planar mechanisms: four-bar mechanism, PRRP mechanism, Scotch Yoke mechanism and Peaucellier mechanism.