Collision-free resolution of 3D kinematic constraints

November 30, 2022

1 Abstract

The GENERAT3D project funded by the French National Research Agency proposes to design a method for synthetic generation of CAD model assemblies. It is in this context that it is essential to automate the process of solving kinematic constraints without collisions so that the generated assemblies remain visually consistent. The goal of this project is to evaluate the advantages and disadvantages of different kinematic solvers available in the literature. Once the choice of the solution has been made, the solution will have to be developed and implemented in Python or C++ in order to be integrated into the open source software FreeCAD.

2 Context

The reverse engineering of mechanical products is more and more used with the arrival of 3D printing accessible to the general public. It consists in finding the digital model of a product from the real product. The numerical methods used to automate the reverse engineering process are increasingly based on machine learning methods. While these supervised learning methods are increasingly used, they are most often limited by the labelled data sets that remain insufficient for mechanical assemblies. To overcome the lack of labelled data, a new method has appeared: synthetic data generation. The GENERAT3D project, funded by the French National Research Agency, proposes to design a method for synthetic generation of CAD model assemblies. It is in this context that it is essential to automate the process of resolving kinematic constraints without collisions so that the generated assemblies remain visually coherent.

3 State of the Art

In order to solve kinematically parametric constraints, and to detect constraint redundancies, many algorithms have been developed in the scientific community. Graph-based approaches and algebraic methods are the most commonly used to solve geometric constraint problems : [2], [1], [5], and are dominant in 2D CAD applications. They have also been extended, more recently, to 3D cases where the management of constraints and the search for solutions are more complex. From a 2D CAD point of view, D-Cubed's algebraic approach, called Dimensional Constraint Manager, is in fact an industry standard in the field of constraint-based sketching. The more recent 3D version of this software, 3D DCM, based on a fast non-sequential solver, is used to constrain parts in assemblies and mechanisms. The FreeCAD opensource software community has created its own A2+ kinematic solver, which solves kinematic constraints iteratively, by adding attractive forces between constrained parts. Its particularity is that it allows to visualize and physically understand the phenomenon of convergence between the parts. It should be noted that there are many solvers that can find a kinematic configuration that can satisfy the placement of one or more parts. These are called Inverse Kinematic Solvers [3] and are most often used to determine the exact placement of a robotic arm during its movement.

4 Objective of the internship

The goal of this project is to evaluate the advantages and disadvantages of different kinematic solvers available in the literature. Different solvers have already been implemented in the FreeCAD modeler [4], [1] and remain completely modifiable. An iterative collisionless solver has been implemented based on the A2+ solver.

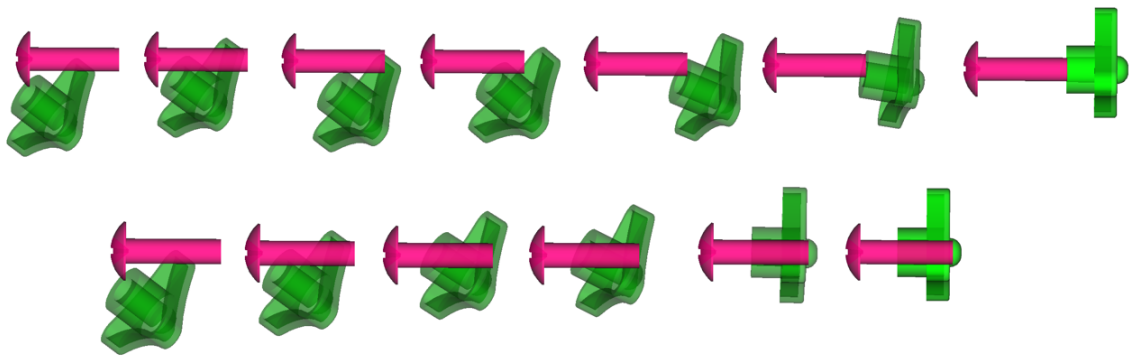

Figure 1: FreeCAD A2+ solver iterations.

Top: kinematic stress resolution without taking into account collisions, and bottom: taking into account collisions on a coaxial stress between a screw and a wing nut. However, this method can become time consuming because of the calculation of collisions between models when the models contain many faces. This is why an integration of collisions in an analytical solution would allow an exact and faster resolution. Once the choice of the solution has been made, the solution will have to be developed and implemented in Python or C++ in order to be integrated into the open source software FreeCAD.

5 Team and laboratory

The internship will take place at LISPEN on the Arts et Métiers campus in Aix-en-Provence. It will be supervised by Jean-Philippe PERNOT (Pr.), Arnaud POLETTE (Associate professor), and Lucas VERGEZ (PhD). They can be contacted at: Jean-Philippe.Pernot@ensam.eu, Arnaud.POLETTE@ensam.eu and Lucas.Vergez@ensam.eu.

References

[1] A2+ solver. $https://github.com/realthunder/FreeCAD_assembly3$.

[2] Solvespace solver. https://solvespace.com/index.pl.

[3] A. Aristidou and J. Lasenby. Inverse kinematics: a review of existing techniques and introduction of a new fast iterative solver. 2009.

[4] K. Brauer. A2+ solver. https://github.com/kbwbe/A2plus.

[5] I. Fudos and C. M. Hoffmann. A graph-constructive approach to solving systems of geometric constraints. *ACM Transactions on Graphics (TOG)*, 16(2):179–216, 1997.