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<u>Theme</u>

Optimal Design of a Planar Parallel Robot with 2'DOF

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Acknowledgment

First of all (El-hamdoulillah), that we have succeeded in reaching this degree and this stage of postgraduate studies, We would like to send our warm thanks to our supervisor

'Mr : MANSOURI KHALED'

for having ensured the direction of this dissertation and for its encouragement throughout this year of work

Dedication

I dedicate this work to my mom for her encouragement and prayers throughout my studies. To my dear father, who gave me all kinds of support.

I dedicate it to my brothers and sisters, and I thank them for their encouragement and assistance, as well as the members of my family. To all my friends without naming names.

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Notations and Abbreviations

Notations:

$\mathbf{O}$	fixed reference frame (base frame).
$\mathbf{O}'$	moving frame (attached to the nacelle).
$\boldsymbol{l}$	Link length [mm].
$\boldsymbol{R}$	Robot outer radius [mm].
$\boldsymbol{r}$	Radius of the nacelle [mm].
$\boldsymbol{q}$	Joint coordinates (shareholders' coordinates) [m].
$\dot{\boldsymbol{q}}$	Linear speed of shareholders [mm / s].
$\boldsymbol{x}$	Center coordinates of the nacelle [mm].
$\dot{\boldsymbol{x}}$	Center nacelle point [mm /s]
$\boldsymbol{J}$	The Jacobian matrix.
$\boldsymbol{I}$	Unit vector.
$\boldsymbol{\kappa}$	Conditioning of the Jacobian matrix.
$\bar{\boldsymbol{\eta}}$	Global condition number.

Abbreviations :

PKM	Parallel Kinematic Manipulators.
GA	Genetic Algorithm.
DOF	Dégrée Of Freedom

General Introduction:

For certain industrial applications, serial kinematics manipulators no longer seem to be the best suited. Indeed, this type of architecture implies that each motorized axis supports the next.
It is for this reason that parallel kinematics manipulators are increasingly used today. Initially, they were used as a flight simulator and as a handling robot with high speeds. Currently, the UGV world, as well as the medical community and industrial companies is opening the doors to them for more and more precise applications. However, it is in terms of precision that the manipulators with parallel kinematics have still not shown their superiority over their counterparts with serial kinematics.

This work concerns the optimal design of a parallel robot with two degrees of freedom, followed by geometric and kinematic study of this system.

This manuscript is divided into 3 parts. After a state of the art of existing architectures for industrial applications and give some definitions. In Chapter II , is dedicated to the geometric, kinematic modeling of the considered robot. We choose the candidate parallel architectures. Among these architectures, we take the Biglid robot in order to design a two-axis machine, that is to say which has only two translations.

Finally, Chapter III deals with the problem of the optimal design of Biglid robots (2 DOF) by taking into consideration kinematic performance as performance criteria and a resolution by the method of the genetic algorithm implemented in Matlab.

Chapter I : State of the art of parallel robots

In this chapter, we first start by presenting parallel robots by stating some definitions and we give a non-exhaustive list of the different architectures found in the literature. We introduce concepts necessary for the analysis and manipulation of parallel robots.

I.1. Introduction

Parallel robots, also called parallel manipulators or parallel kinematic machines (PKM), are defined as robots that control the motion of their end-effectors by means of at least two kinematic chains going from the end-effect or towards the fixed base. From this definition, we see that the PKM are composed of different elements (Figure I.1):

• The (fixed) base, which is the fixed element of the robot

• The (moving) platform on which is usually mounted the end-effector,

• The kinematic chains, linking the base to the platform, and also called the robot legs. A leg is usually a kinematic chain of serial or tree-structure type (Figure I.2 and Figure I.3).

Parallel robots are very attractive for several applications because the manipulated load is shared by several legs of the system. Consequently, each kinematic chain carries only a fraction of the total load, which allows the creation of intrinsically more rigid robots. Such architectures also make it possible to reduce the mass of the movable links (all the actuators are mainly fixed on the base and many legs are stressed by tension/compression efforts) and, as a result, make it possible to use less powerful actuators. Such characteristics promised to create structures with high payload, high dynamic capacities and high accuracy. Nowadays, parallel robots are used for several applications, such as (the list is not exhaustive)[1] :

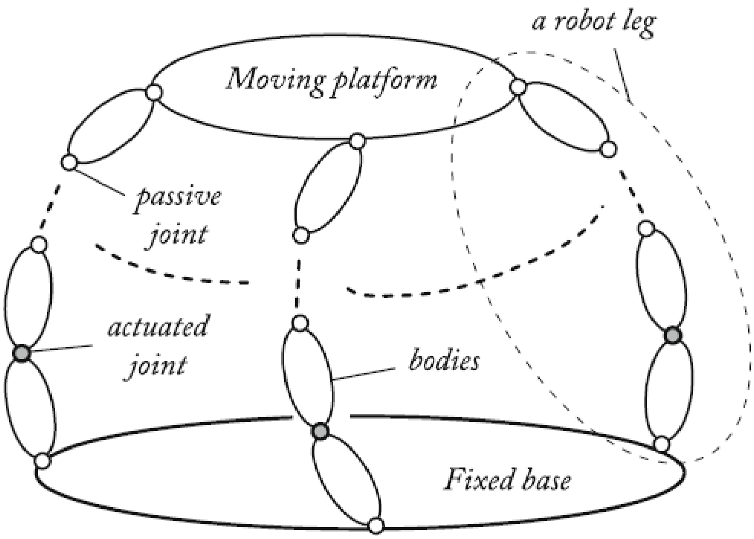


Figure I.1. *A general parallel robot (the gray joints denote the actuated joints)*

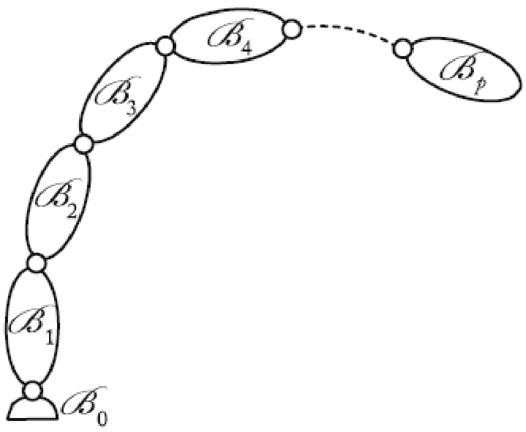


Figure I.2. *Schematics of a serial open kinematic chain*

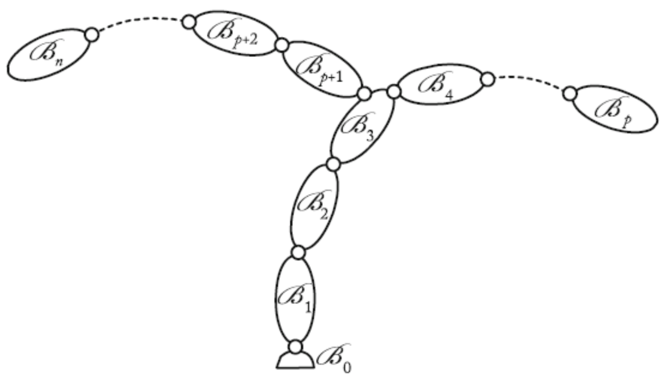


Figure I.3. *Schematics a tree-structure open kinematic chain*

I.2. General Definitions :

we define the following terms as:

• Mobility: the mobility of a body is defined as the number and types of independent components of its twist (rotational and translational velocity components).

It is equal to six for a free body in space and three for a body in plane.

• Degree of freedom: the number of degree of freedom (DOF) of a body is defined as the number (only) of independent components of its twist.

• Lower mobility robot: a robot with a mobility of the platform inferior to six.

• Robot with a mobility i T j R: a robot whose platform encounters i translational DOF and j rotational DOF.

• Joint: A joint connects two successive links, thus limiting the number of degrees of freedom between them. The resulting number of degrees of freedom, m, is also called joint mobility, such that $0 \leq m < 6$. When $m = 1$, which is frequently the case in robotics, the joint is either revolute or prismatic. A complex joint with several degrees of freedom can be constructed by an equivalent combination of revolute and prismatic joints. For example, a spherical joint can be obtained by using three revolute joints whose axes intersect at a point.

• Active joint: a joint which is actuated.

• Passive joint: a joint which is not actuated.

• R joint: a revolute joint (Figure I.4), allowing a rotation around a given axis. If the letter is underlined (R joint), the joint is actuated. If not, it is passive.

• P joint: a prismatic joint (Figure I.5), allowing a rotation around a given axis. If the letter is underlined (P joint), the joint is actuated. If not, it is passive.

• U joint: a universal joint, allowing two independent rotations around two given axes. These joints are usually passive and can be represented by two R joints with orthogonal and intersecting axes.

• S joint: a spherical joint (Figure I.6), allowing three independent rotations. These joints are usually passive and can be represented by 3R joints with orthogonal and intersecting axes.

• Joint variable / coordinate: a variable/coordinate associated to the motion of a given joint.

• Cartesian variable / coordinate: a variable/coordinate associated to the Cartesian position and orientation system. It is generally used to characterize the motion of the platform.

• Singularity or singular configuration: a configuration for which the mechanism loses the ability to move along one given direction of the workspace and/or gains one uncontrollable motion. Moreover, locally, the robot mechanical performance (stiffness, accuracy, etc.) are locally decreased.

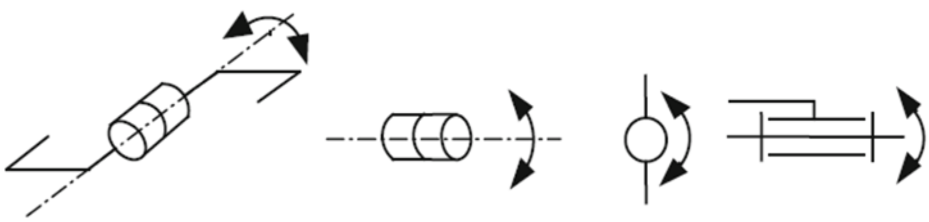


Figure I.4. *Symbolic representation of a revolute joint*

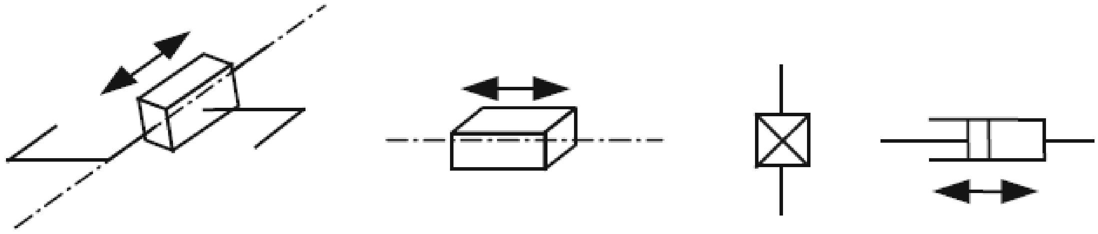


Figure I.5. *Symbolic representation of a prismatic joint*

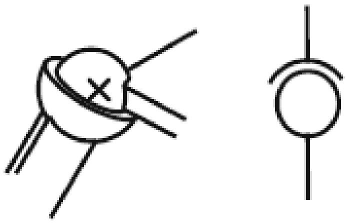


Figure I.6. *Symbolic representation of a spherical joint.*

I.3. The advantages of parallel robots:

The main qualities associated with parallel robots in the literature are:

- A transportable mass / mass in motion ratio of the robot much higher than that of serial robots.
- Good rigidity due to closed kinematic chains.
- Good dynamics because the moving masses are generally low.
- Better accuracy than serial robots.

I.4. The disadvantages of parallel robots:

The main shortcomings of parallel robots are:

- A Geometric Direct Model (MGD) often complex.
- A low work volume compared to the size of the machine.
- Amplitudes in orientation often limited due to singularities and internal collisions a very large number of possible topologies.

I.5. Degrees of freedom:

We define the degrees of freedom of a mechanism as being the set of movements achievable by the terminal organ among the three translations along the axes x, y, z and the three rotations (around the axes x, y, z). Note that these three vectors define a fixed coordinate system whose axis z is very often the axis orthogonal to the work plane.

After analyzing the applications that can be considered as "pick-and-place", we find that the six DOF are not useful. In fact, in an industrial context, these robots are used to transfer parts from one work surface (for example, a conveyor) to another. These planes being parallel to each other, the rotations around the x and y axes are not useful; only rotation around the z axis may be necessary (in the rest of this manuscript the angle relating to this rotation will be named θ). On the other hand, the part to be handled must be able to be moved as much as possible according to the three translations x, y, z.

Based on this observation Brogårdh offers a classification[2] giving the number of DOFs useful for the most common industrial applications.

We can mention the most important types of DOF's:

I.5.1. Two degrees of freedom:

In very simple cases of slow or intermittent production lines, only two DOF are needed: translations according to x and z (2T architecture).

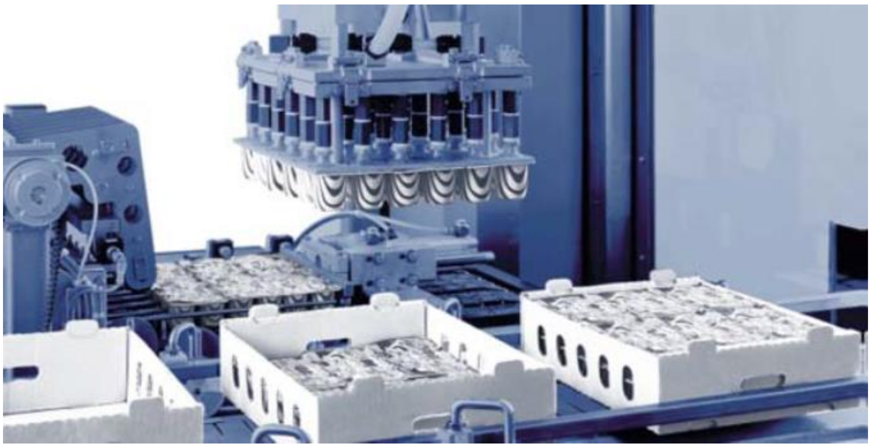


Figure I.7. *Example for a 2T mechanism*

The example shown in Figure I.7, the intermittent movement of the line allows the robot to move only in x and z. In addition, rotation around the z axis is not useful because the products do not need to be oriented.

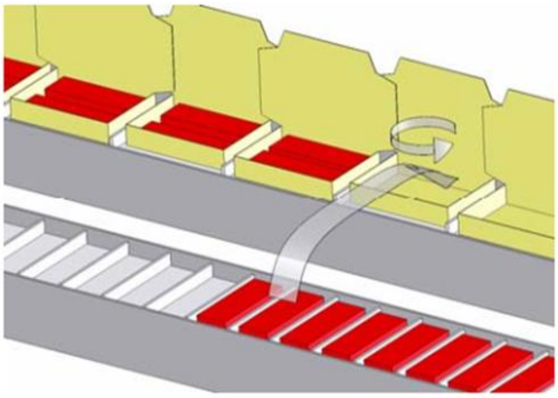
I.5.2. Three degrees of freedom:

I.5.2.1. 2T1R :

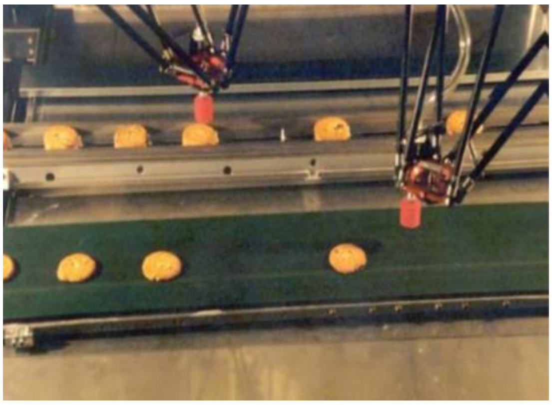
The 2T1R mechanisms are used in applications whose characteristics are similar to the previous case (very slow or intermittent line), but the object to be manipulated needs to be oriented. The DOF of these mechanisms must therefore be two translations in x and z and a rotation around z. An example of this type of application is presented in Figure I.8.a

I.5.2.2. 3T :

In the case of rapid applications for which conveyor tracking is essential, the terminal member of the robot must be able to move according to the three translations x, y, z. Indeed, tracking consists in taking an object in movement on a moving conveyor, and to deposit it on another conveyor. The latter can itself be moving in the same direction as the first, in the opposite direction (back flow) or perpendicular to the first. An example of this type of application is shown in Figure I.8.b.



(a) Application requiring a 3T mechanism



(b) Application requiring a 2T1R mechanism

Figure I.8. *Examples of applications using 3 degree of freedom mechanisms*

I.5.3. Four degrees of freedom:

Four-DOF mechanisms are used for applications requiring great flexibility. The products to be handled can be presented on the work surface in a disorderly and moving manner.

A vision system is often used to identify the position of the product and its orientation. The robot must therefore be able to move the products along the three translations x, y, z and orient it using a rotation around the z axis, as shown in Figure I.9.

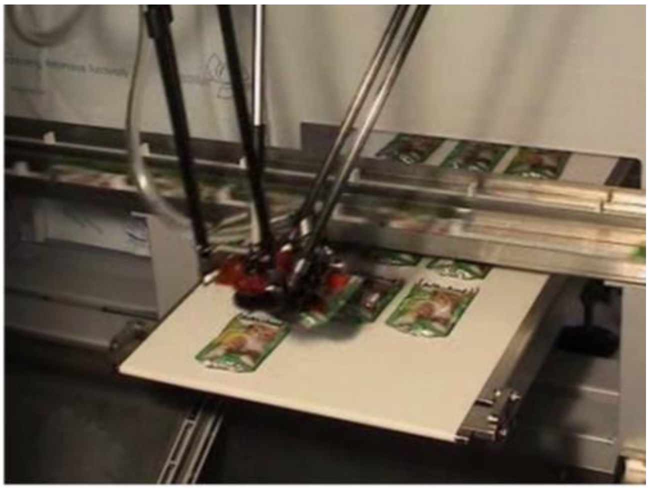


Figure I.9. *Example of a robot with four degrees of freedom*

I.6. Architecture of parallel robots:

I.6.1. Planar Motions of the Platform :

A planar robot generally consists of a platform, comprising three degrees of freedom: two translations and a rotation around the normal to the plane of the platform.

We are looking for a fully parallel robot structure, therefore having three independent kinematic chains motorized by three actuators. Each of these chains must be linked to both the ground and the mobile platform, so we will have three points of attachment to the ground and to the mobile platform. We can therefore consider without loss of generality a triangular platform.

I.6.2. Spatial Motions of the Platform :

In parallel space robots, the platform and the base are connected together by kinematic chains ensuring three or six degrees of freedom to the platform.

The most well-known robot with three degrees of freedom in translation is the Delta initially developed at the Polytechnic School of Lausanne by the team of PrClavel [3], And the best known for parallel robots with six degrees of freedom is the Gough-Stewart platform [4],[5] belongs to the hexapod family. Today it is known as the Stewart platform. Merlet [6] describes three concepts of structures with six degrees of freedom with base and a platform linked together by six linear actuators.

I.7. Parallel robots existing:

I.7.1. Robots with two degrees of freedom:

The two DOF architectures used for pick-and-place are mechanisms capable of performing two translations. Depending on the case, and especially depending on the applications, it is possible to constrain or not the orientation of the terminal member of the robot.

I.7.1.1. Two translations, orientation of the end organ unconstrained

Architectures which do not impose the constant orientation of their terminal organ are most often used as subsets of hybrid robots. This is for example the case of the robot "ParaPlacer", developed by the IFW presented in Figure I.10.

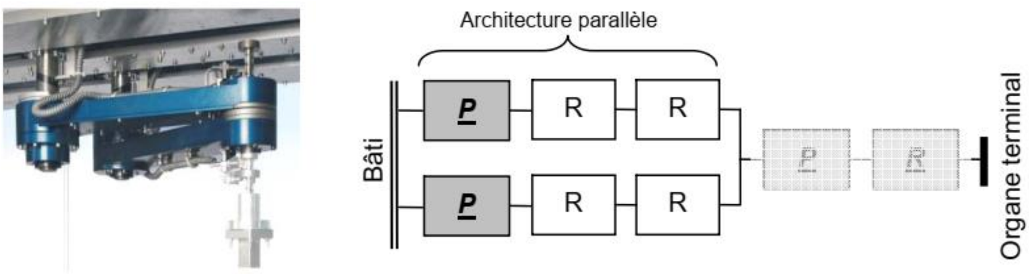


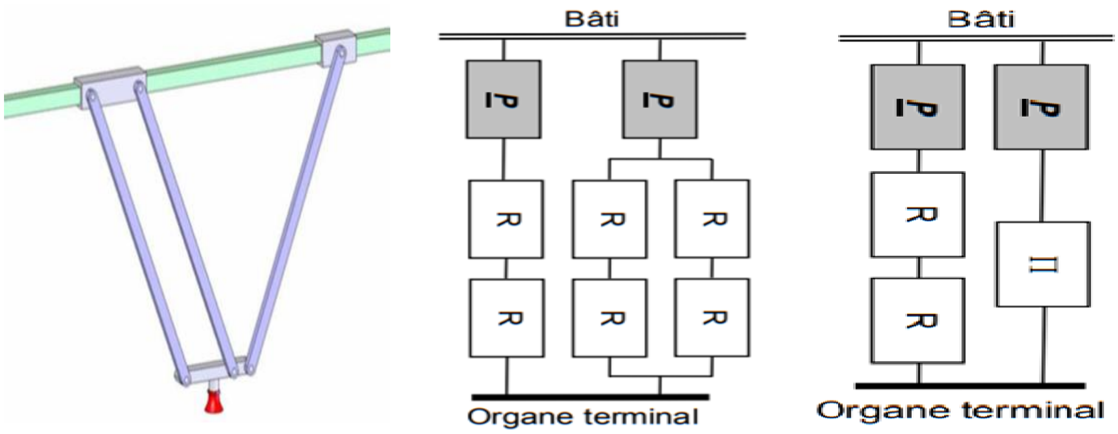
***Figure I.10.**.Hybrid mechanism using a parallel architecture with 2 degrees of freedom of step constraint the orientation of the terminal organ*

This robot is in fact composed of a first part produced using a parallel architecture imposing displacements in x and y, and two other DOF (translation in z and rotation θ) obtained using a mechanism additional placed in series at the end of the parallel part.

I.7.1.2. Two translations, orientation of the constrained terminal organ:

Mechanisms capable of carrying out two translations and whose orientation of the terminal member is forced to remain constant are much more used in pick-and-place applications. This constraint is obtained using a plane parallelogram which allows only a circular translational movement between two solids.

This articulation "composed" is called link Π [7]. Thus, in the mechanism proposed by Brogårdh [8] and presented in Figure I.11.a link Π located between the prismatic actuators and the terminal member ensures the constant orientation of the nacelle.Figure1.14b, c shows the two representations which can be adopted for this link Π



(a) Representation of the mechanism (B) Graph of complete arrangement (c) Layout graph using the representation of the bond Π

Figure I.11. *Robot with two degrees of freedom constraining the orientation of the nacelle with prismatic actuators*

The first graph shows its complete representation, that is to say four rotoid links in closed chains, and the second defines an undeveloped representation of this link. In the rest of this manuscript, this representation will be adopted. Neighboring mechanisms can also be constructed using rotary actuators as shown in Figure I.12.

(a) representation of the mechanism b) representation of the mechanism whose parallelograms are far apart singular positions c) layout graph

Figure I.12. *Robot with two degrees of freedom with rotary actuator*

Figure I.12c shows that the actuation of these architectures takes place via the links liaisons, that is to say on one of the rotoid links which make up this joint. It is also a good idea to modify these mechanisms by changing the layout of the planar parallelograms (see Figure I.12b) in order to distance the working position from the internal singularities of the four-bar system making the connection Π.

Finally, the mechanisms presented in Figure I.12 can be constructed using the "lambda" constructive arrangement. This defines the particular position of the joint connecting two solids. Indeed, this link is placed on a segment, and not at its end.

A known example using this concept is none other than the actuation of the Stewart platform [5]. The advantage of using this "lambda" provision is either to be able to modify the type of actuation Figure I.13.(a) Or to reduce the space requirement at the platform Figure I.13.(b). Note that the robot presented to the Figure I.14.(a) has actuators in motion. This type of architecture is therefore more suitable for handling heavy loads rather than high speed movements.

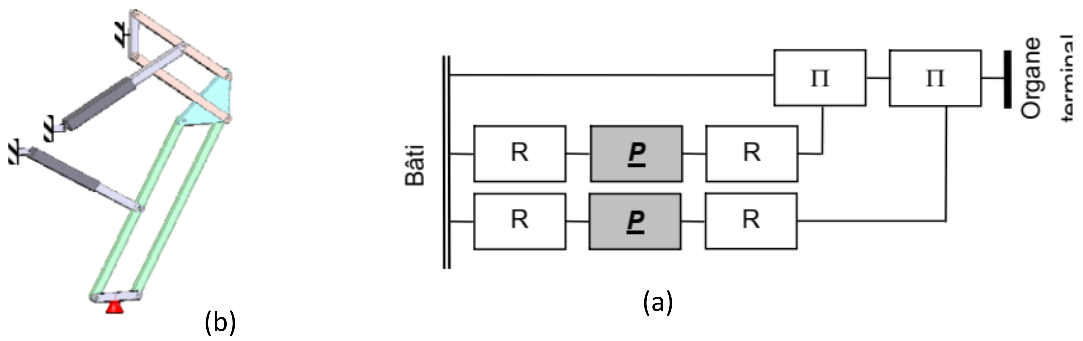


Figure I.13. *modeling and layout graph use of the lambda concept to modify.*

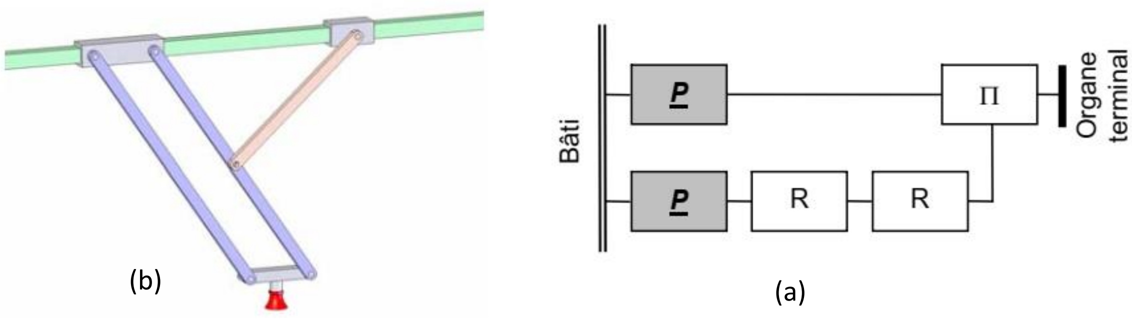
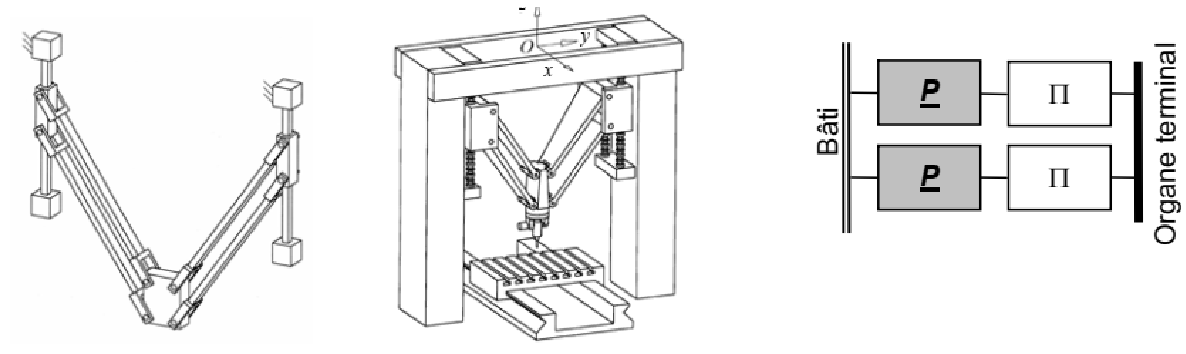


Figure I.14. *modeling and layout graph: use of the lambda concept to reduce clutter.*

Finally, we can cite the mechanism proposed by Liu[9] using two links Π connecting the nacelle to the prismatic actuators positioned vertically (cf. Figure I.15a and b).



(a) Principle of the mechanism *b) Example of use (machine tool)* *(c) Layout graph*

Figure I.15. *Hyper static mechanism using two vertically positioned prismatic actuations*

This architecture was proposed to make a hybrid machine tool (right hand / left hand) the third axis is obtained by translation of the table) as presented in Figure I.15b.

I.7.2. Robots with three degrees of freedom :

I.7.2.1. Robot with three degrees of freedom (2T1R) planes :

Few studies have been conducted on robots capable of producing three DOF Plans, or two translations in x and z and a rotation around the z axis. We can however cite a mechanism proposed by Brogårdh [10] which has these nobilities . It is composed of a plane base composed of a chain **Π** Π and of a **R**R joint producing two translations in x and z. At the end of this base, a joint Π is activated via an **R**SS chain producing rotation around the z axis (see Figure I.16).

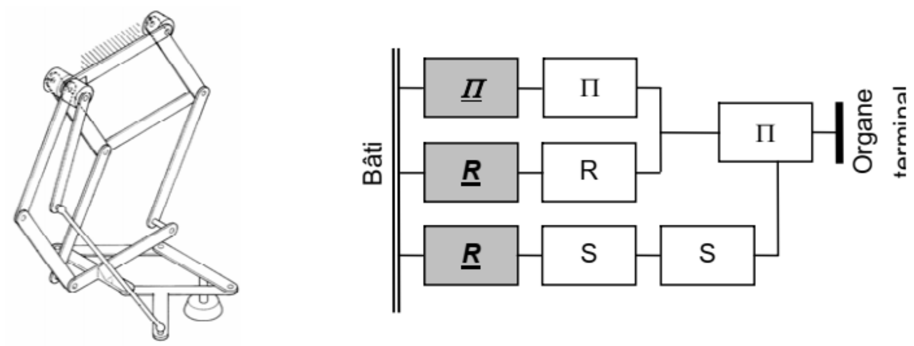
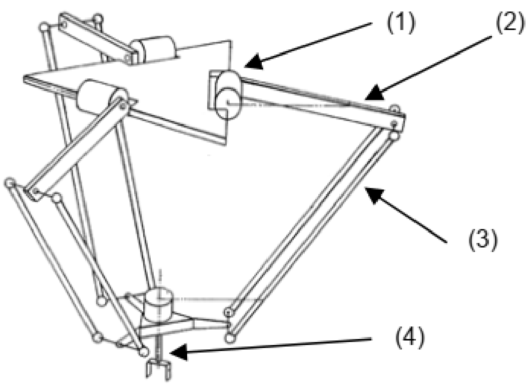


Figure I.16. *Representation and layout diagram of the 2T1R robot proposed by Brogårdh*

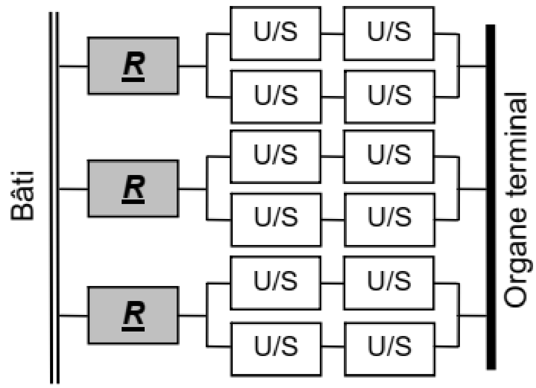
Although this type of robot has a strong industrial interest, the mechanism proposed by Brogårdh has the major drawback of having a limited rotation of ± 45 °.

I.7.2.2. The Delta robot :

The Delta robot was created in 1985 at the Federal Institute of Technology in Lausanne (EPFL) by Clavel. Originally, this robot was equipped with three rotary motors (1) (cf. Figure I.17a) connecting a nacelle (4) via three identical kinematic chains. These are composed of an arm (2) and a four-bar closed chain system (3). This system is commonly called "spatial parallelogram" because its function is to guarantee the parallelism between two solids in space, provided that the bars remain coplanar two by two (which is verified on a Delta when all the kinematic chains are assembled). It is generally carried out using spherical connections, but a pair of these connections can be replaced by a pair of cardan connections in order to eliminate the internal mobility of the bars. All the connections can also be replaced by universal joints (see Figure I.17b), but this solution has the consequence of over-stressing the structure.



(a) Modelization



(b) Graphe d'agencement

Figure I.17. *Representation and layout diagram of the Delta robot*

The Delta concept can be declined in many versions. First, the rotary actuators (1) can be replaced by linear actuators as shown in Figure I.18. In addition, the robot will have the same kinematic behavior (but not the same rigidity) if the spatial parallelograms (3) are replaced by simple bars provided that cardan links are used. Finally, it is possible to add a fourth DOF to this mechanism via an additional kinematic chain.

Many of new architectures are largely inspired by this concept, and this robot was the first of a long line of architectures with 3 and 4 DOF.

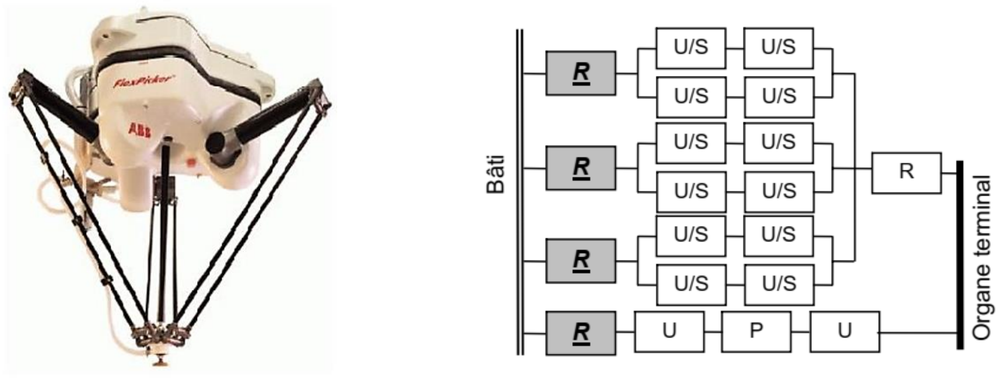
Figure I.18. *Manipulator using the Delta architecture with linear actuators*

I.7.3. Robots with four degrees of freedom:

The four DOF mechanisms are the most used especially in the pick-and-place because of their great flexibility of use. Indeed, in the case of the manipulation of objects, the useful DOF are the three translations in x, y, z and the rotation around z. All of these displacements are today called "SCARA movements" or " Schoen flies displacement group [11]. Of course, it is possible to take the concepts developed in § 1.2.2 and add an "on-board" actuation to them, but the dynamic performance of these mechanisms would then be degraded. The robots presented in this paragraph are therefore fully parallel architectures or with remote actuation, thus allowing good dynamic capacities to be preserved.

I.7.3.1. The Delta with four degrees of freedom:

In order to meet the needs of object manipulation applications, the Delta architecture, originally provided with three DOFs (cf. § I.7.2.1), was modified to add a fourth mobility. Thus, rotation is obtained by adding a rotoid connection to the platform, the rotation of which is controlled using a kinematic chain of RUPU type (see Figure I.19). This "telescopic leg" allows unlimited rotation, but has the major drawback of limiting the dynamic performance of the modified Delta, all the more so for large robots. In fact, the reliability and the lifespan of this passive tab are reduced when the robot performs movements whose accelerations are significant. It is therefore difficult to find a compromise between the dimensioning of this tab and the limitations which it imposes on the mechanism.



(a) Photo (b) Layout graph

Figure I.19. *Representation and layout graph of the Delta with 4 degrees of freedom (ABB)*

The recent evolution of this type of architecture has known two major stages: the creation of the first hexapod in the 1950s and the development of the first "light parallel robot" in the 1980s[3].

I.7.4. Robots with six degrees of freedom :

I.7.4.1. The era of hexapods :

The first representative of this family is the Gough platform[4]. This six-DOF mechanism was intended for testing tire behavior. It is made up of six kinematic chains connecting the nacelle to the frame. Each of these chains, actuated by a hydraulic cylinder, is connected on the one hand to the frame by a universal joint and on the other hand to the nacelle by spherical connections. The principle proposed by Gough was taken up by Stewart[5] whose goal was to create a flight simulator using a neigh boring architecture.

Even if the actuators of these two architectures are in motion, their dynamic performance, although limited, is already better than that of robots of the series type. In addition, Gough and Stewart realized their mechanisms using parallel architectures in order to distribute the loads transported on the six kinematic chains. These robots are therefore capable of moving large masses, while ensuring good precision.

I.7.4.2. The era of light parallel robots :

This generation of robot is much more recent than hexapods. Its first representative was the Delta developed by Clavel in the 1980s [12] at Federal Polytechnic School of Lausanne

(EPFL). It was the first parallel robot with less mobility than the usual six DOFs. Note that this architecture will be presented in more detail in § I.7.2.1.

The main characteristic of these robots is not the ability to move heavy loads, but to reach very high dynamics. Indeed, the moving masses of these robots are minimal: the motors are all fixed to the chassis and the parts used are of very reduced masses.

Light parallel robots on the market are currently capable of reaching speeds of the order of 4 to 5 m / s and accelerations of 10 g in all directions of the work volume. In a version using direct drive motors, the EPFL prototype was even able to reach accelerations of 50 g[13] . This performance was achieved with a version of the robot with three DOF during simple movements.

Another example of a light parallel robot is the Hexa [14] . This six-DOF mechanism is made up of six kinematic chains activated by rotary motors.

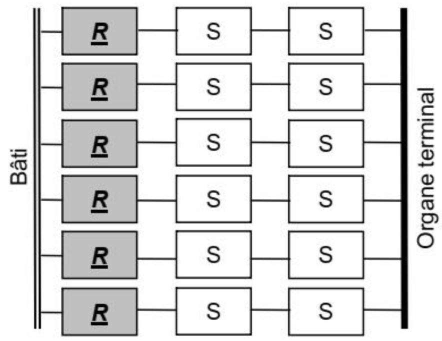


Figure I.20. *Photo and layout graph of the Hexa robot*

Because they have very high dynamic capacities, these robots are particularly well suited to rapid handling applications.

I.8. The main differences between Parallel and Serial robots :

One of the basic objectives in robotics is the ability to move objects according to prescribed trajectories. The goal is to replace humans when carrying out strenuous tasks or those presenting a risk to the body. The design of the manipulators was therefore naturally inspired by a serial architecture called anthropomorphic, comprising a shoulder, an arm and a wrist. The resulting mechanical characteristics strongly influence the performance of the robot. Thus, for these manipulators with serial architecture, the payload / mass ratio of the robot does not exceed 0.1 for a spherical robot with 6 degrees of freedom and 0.2 for robots of the SCARA type. These serial structures have other drawbacks, including in particular a lack of compactness and precision in the positioning of the terminal effector due essentially to the accumulation of errors in each segment making up the manipulator.

Research, in the minimization of these constraints has allowed the development of the concept of robot with parallel architecture [4], characterized by a fixed base and a mobile platform linked together by independent kinematic chains[15], thus giving it a great rigidity. It was not until the late 1970s and early 1980s that parallel manipulators began to attract the attention of mechanics and roboticists as a possible alternative to serial structures. To further increase the performance of these manipulators, hybrid architectures have been developed which combine the advantages of serial and parallel manipulators while minimizing their shortcomings[16-20].

Four fundamental aspects differentiate robots with parallel architecture and classic serial robots[21-23]:

I.8.1. The workspace :

This is the space that can be reached by the terminal organ. In the case of a parallel robot, this space or the accessibility of the capacity is limited compared to the series robots. This is why redundancy is an interesting area concerning parallel robots to increase the work space of the robot [24, 25].

I.8.2. The transportable mass / robot mass ratio :

In classic series architecture, the terminal member is at the end of the articulated chain. Each actuator must have the necessary power to set in motion all the bodies and actuators downstream. In the case of parallel robots, the actuators are most often located in the vicinity of the articulation points of the base, if not on the base itself, which gives a much more transportable mass / required robot mass ratio.

I.8.3. Precision and repeatability :

For serial robots, a positioning error on one or more joints has repercussions on the final position of the terminal organ. This problem of accumulation of errors does not arise for parallel robots since its morphology ensures remarkable rigidity even with very light mobile structures.

I.8.4. Dynamic behavior:

Given their structure, serial robots have limited dynamic performance. With parallel robots, reducing the inertia of the robot helps to reduce the effects of dynamic coupling. Parallel robots have many advantages for pick-and-place tasks (picking up and placing an object), notably thanks to their high velocity.

Table I.1. summarizes *the main differences between these two architectures.*

Serial manipulator	Parallel robot
= Succession of serial segments from base to effector	= Any segment is in contact with the base and the effector
= Open kinematic chain	= Closed kinematic chain
+ Large workspace	- Restricted workspace
- Low precision	+ High precision
- Low transportable load	+ Heavy transportable load
- Low rigidity	+ Very rigid

I.9. Conclusion

This chapter provided general information about robotics, the definition of robots, and some important parts and terms in the world of robotics, as well as the important families in the world of robotics were mentioned, as well as the difference between them, their pros and cons, then we focused on the subject of study and separated the family of parallel robots.

Chapter II: modeling of parallel manipulators with 2’DOF

Chapter II: modeling of parallel manipulators with 2’DOF

In this chapter, we introduce parallel robotics in the field of robotics, choose the parallel planar robot in 2DoF, and finally we model equations important in optimizing the position and movement equations and their relationships and the Jacobian matrix.

II .1. Introduction :

The applications of parallel manipulators are multiple [26]. Although their initial applications were flight simulators and tire testers [4] [27] [28], they have appeared in areas where speed, acceleration and precision are essential. We find for example these manipulators in the field of remote operation [29]. Another more recent application is the use of parallel manipulators for machine tools. Indeed, to increase the production of machining centers, the feed speeds and the spindle rotation speeds have increased considerably. This new technology is "high machining speed" [30]. Among these new machining machines, the Hexapod [31] is one of the best known. Significant problems remain with regard to trajectory planning and the implementation of simulation software. However, the intrinsic qualities of parallel manipulators must make it possible to achieve the objectives of high machining speed. Parallel robots are also designed to operate in a limited workspace, which represents a safety advantage in certain medical applications. The design of new medical robots is geared towards the development of medium-sized micro-robots and robots for medical applications using parallel structures and trying to better meet the needs of surgeons.

The field that has come to be called parallel robotics is much less developed than that of serial robotics. However, the large number of publications dealing with this field continues to grow, proving the growing interest it arouses. The work mainly concerns the following points:

II .1.1. Geometric modeling :

The resolution of direct and inverse geometric models is an important problem in robotics and more generally in the study of manipulators.

The inverse geometrical model of a parallel manipulator must make it possible to find all the articular configurations making it possible to place the platform of the manipulator in the desired configuration. The resolution of this type of modeling does not generally pose any problem.

The resolution of the direct geometric model of fully parallel manipulators is a complex problem. Its difficulty is comparable to that of the inverse geometric model for serial manipulators. Thus, a lot of research has been done to solve the following problems [32]:

▪ finding the maximum number of real solutions.

▪ the rapid search for a solution from a known configuration.

▪ the simplification of the model by adding additional sensors.

II .1.2. Calibration :

The practical use of direct and reverse kinematics requires a perfect knowledge of certain geometric elements of the robot [24] [33]. Errors in the geometric parameters of the robot lead to a difference between the actual position of the final effector and the desired one. This difference can be evaluated by measuring the position of the final effector, then using it in an optimization procedure which determines the values of the parameters, reducing positioning errors. There are two types of calibration methods [24, 33]:

▪ The external method: an external measuring device is used to determine (completely or partially) the actual position of the platform for desired configurations different from the platform. The differences between the measured and desired positions give an error signal which is used for calibration [34-39].

▪ The self-calibration method: the platform has additional sensors and only the robot's measurements are used for calibration [40-42].

▪ The first method is difficult to use in practice but gives good results. The second method may be less precise, but it is easy to use. An interesting problem is to determine the measured configurations of the platform that lead to better calibrations, or in fact the search for an upward trajectory.

II .1.3. Study of the workspace :

The workspace defines the volume of configurations accessible from the mobile platform. There are several projections of the workspace:

▪ The maximum workspace, which corresponds to all the positions accessible by the mobile platform.

▪ The Dexter workspace, which corresponds to all the positions accessible by the mobile platform for all of its orientations.

▪ The constant orientation workspace, which corresponds to all the positions accessible by the mobile platform for a given orientation.

II .1.4. The study of singular configurations :

For all the manipulators, of serial or parallel type, one finds configurations known as singular where the number of degrees of freedom of the mobile platform is different from the dimension of the operational space in which it evolves [32] [43-46].

Thus, a fully parallel manipulator can gain or lose one or more degrees of freedom. In addition, these configurations can be located on the border of the workspace, as for serial manipulators, as well as inside. These singularities will be the most disturbing for the generation of trajectories. Therefore, in the vicinity of these singularities, we encounter the following problems:

▪ A significant increase in the forces in the joints which can damage the structure of the manipulator.

▪ A loss of rigidity of the manipulator, which can result in instability of the mobile platform. That is to say uncontrolled movements thereof while the motorized joints are blocked.

To find these singular configurations, there are two approaches. The first method is an analytical method based on the study of the manipulator's Jacobian matrices [47-49]. The second method is a geometric method using Grassmann geometry [32].

II .2. Structure Description:

The 2-DOF parallel manipulator is shown in Figure II.1. The mechanism is composed of a gantry frame, a moving platform, two active sliders, and two kinematic chains. Each chain is built as a parallelogram. As designed, the manipulator is over-constrained since one parallelogram link and another single link are enough before the moving platform possesses 2 translational DOFs. Two parallelogram chains were used to increase the stiffness and make the structure symmetric.

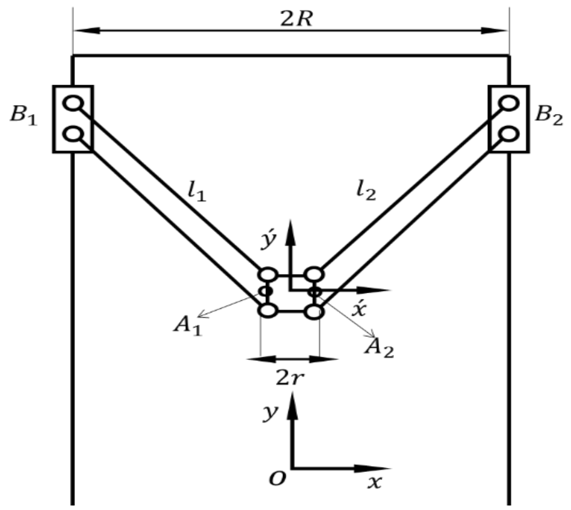


Figure II.1 . *Kinematic model*

The sliders are driven independently by two servo motors on the columns to slide along the guide ways mounted on the columns, thus moving platform with a 2-DOF purely translational motion in a plane.

II .3. Kinematics and Singularities :

II .3.1. Inverse kinematics :

Since the motions of two links of each kinematic chain are identical due to the parallelogram structure, the chain model can be simplified as a link A_iB_i (i = 1,2) .

As illustrated in Figure II.1. The base coordinate system O-xy is attached to the base with its y axis vertical through the midpoint of $\overline{B_1B_2}$. A moving coordinate system O-xy is fixed on the moving platform r_{A_i} and r_{B_i} are the position vectors of the joint positions A_i and B_i, respectively. 2r is the moving platform width and 2R is the width between the two columns. The position vector of the origin O' with respect to the coordinate system O-xy is defined as :

$$\boldsymbol{r_{O'}} = [\boldsymbol{x} \quad \boldsymbol{y}]^{\boldsymbol{T}} \tag{II.1}$$

The position vector of joint position A_i in O'-x'y' is:

$$\boldsymbol{r'}_{\mathbf{A_1}} = [-\boldsymbol{r} \quad \mathbf{0}]^{\boldsymbol{T}} \tag{II.2}$$

$$\boldsymbol{r'}_{\mathbf{A_2}} = [\boldsymbol{r} \quad \mathbf{0}]^{\boldsymbol{T}} \tag{II.3}$$

Then the position vector of A_i in the base coordinate system *O-xy* can be expressed as :

$$\boldsymbol{r'}_{\mathrm{A}_2} = \boldsymbol{r'}_{\boldsymbol{O'}} + \boldsymbol{r'}_{\boldsymbol{A}_{\mathrm{i}}} \tag{II.4}$$

The position vector of joint position B_i in O-xy is:

$$\boldsymbol{r}_{\boldsymbol{B}_1} = [-\boldsymbol{R} \quad \boldsymbol{q}_1]^{\boldsymbol{T}} \tag{II.5}$$

$$\boldsymbol{r}_{\boldsymbol{B}_1} = [\boldsymbol{R} \quad \boldsymbol{q}_2]^{\boldsymbol{T}} \tag{II.6}$$

Thus, the constraint equation associated with the i-th kinematic chain can be written as :

$$r_{A_{\mathrm{i}}} - r_{B_{\mathrm{i}}} = l_{\mathrm{i}} n_{\mathrm{i}} \ , \ i = 1{,}2 \tag{II.7}$$

Where l_i and n_i denote the length and the unit vector of the *i*-th link, respectively. Taking the 2-norm of both sides of equation(II.7) give :

$$\boldsymbol{q}_1 = \boldsymbol{y} \pm \sqrt{\boldsymbol{l}_1{}^2 - (\boldsymbol{x} - \boldsymbol{r} + \boldsymbol{R})^2} \tag{II.8}$$

$$\boldsymbol{q}_2 = \boldsymbol{y} \pm \sqrt{\boldsymbol{l}_1{}^2 - (\boldsymbol{x} + \boldsymbol{r} - \boldsymbol{R})^2} \tag{II.9}$$

For the configuration shown in Figure II.1, the inverse solutions of the kinematics are:

$$\boldsymbol{q}_1 = \boldsymbol{y} + \sqrt{\boldsymbol{l}_1{}^2 - (\boldsymbol{x} - \boldsymbol{r} + \boldsymbol{R})^2} \tag{II.10}$$

$$\boldsymbol{q}_2 = \boldsymbol{y} + \sqrt{\boldsymbol{l}_1{}^2 - (\boldsymbol{x} + \boldsymbol{r} - \boldsymbol{R})^2} \tag{II.11}$$

From equations (II.10) and (II.11), the solutions for the direct kinematics of the manipulator can be expressed as : $\boldsymbol{Ay^2 + By + C = 0}$

$$(\boldsymbol{a}^2 + \boldsymbol{1})\boldsymbol{y}^2 + \boldsymbol{2}(\boldsymbol{ab} + \boldsymbol{\gamma a} - \boldsymbol{q}_1)\boldsymbol{y} + \left(\mathbf{q}_1^2 + \boldsymbol{b}^2 + \boldsymbol{2\gamma b} + \boldsymbol{\gamma}^2 - \boldsymbol{l}^2\right) = \boldsymbol{0} \tag{II.12}$$

Where :

$$\boldsymbol{a} = \frac{\boldsymbol{q}_1 - \boldsymbol{q}_2}{\boldsymbol{2}(\boldsymbol{R} - \boldsymbol{r})} \qquad \boldsymbol{b} = \frac{\boldsymbol{q}_2^2 - \boldsymbol{q}_1^2}{\boldsymbol{4}(\boldsymbol{R} - \boldsymbol{r})} \qquad \boldsymbol{c} = \frac{\boldsymbol{l}_1^2 - \boldsymbol{l}_2{}^2}{\boldsymbol{4}(\boldsymbol{R} - \boldsymbol{r})} \qquad \boldsymbol{\gamma} = (\boldsymbol{R} - \boldsymbol{r})$$

$$\boldsymbol{x} = \boldsymbol{ay} + \boldsymbol{b} + \boldsymbol{c} \tag{II.13}$$

For the configuration as shown in Figure II.1, We should be take the solution y_i (i=1,2)only "-". Equations (II.7) (II.13) show that the direct and inverse kinematics of the manipulator can be described in closed form.

II .3.2.Singularity analysis

Taking the derivatives of equations (II.10) and (II.11) with respect to time gives :

$$\dot{q}_1 = \dot{y} - \frac{x-r+R}{\sqrt{l_1{}^2-(x-r-R)^2}}\dot{x} \tag{II.14}$$

$$\dot{q}_2 = \dot{y} - \frac{x-r+R}{\sqrt{l_1{}^2-(x+r-R)^2}}\dot{x} \tag{II.15}$$

Equations (II.14) and (II.15) can be rearranged in matrix form as

$$\begin{bmatrix}\dot{q}_1\\ \dot{q}_2\end{bmatrix} = J\begin{bmatrix}\dot{x}\\ \dot{y}\end{bmatrix} \tag{II.16}$$

Where $\mathbf{J}$ is the Jacobian expressed as (II.1)

$$\mathbf{J} = \begin{bmatrix} -\frac{x-r+R}{\sqrt{l_1{}^2-(x-r-R)^2}} & 1 \\ \frac{x+r-R}{\sqrt{l_1{}^2-(x+r-R)^2}} & 1 \end{bmatrix} \tag{II.17}$$

Since singularities lead to lost controllability and debasement of the regular solidness of the controllers, they should be stayed away from in the undertaking workspace. Singularities can be named direct kinematic singularities, inverse kinematic singularities [47], and joined singularities, and can be recognized by the controller Jacobian. At the point when one of the links is horizontal, the controller encounters an inverse kinematic singularity.

Direct kinematic singularities occur when one link of a chain and a link of the other chain are collinear. Since $l_1 + l_2 > 2R$ combined singularities cannot occur in this manipulator. Figure II.2 shows one example of each kind of singularity. In practical applications, singularities are avoided by limiting the task workspace.

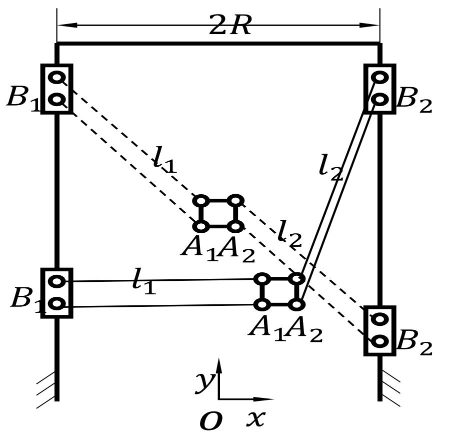


Figure II.2 . *Singular configurations*

II .4. Workspace Analysis:

The workspace for the 2-DOF planar parallel manipulator is a region of the plane derived by the workspace of the reference point *O'* of the moving platform. Equations (II.10) and (II.11) can be rewritten as

$$(\mathbf{x} - \mathbf{r} + \mathbf{R})^{\mathbf{2}} + (\mathbf{y} - \mathbf{q_1})^{\mathbf{2}} = \mathbf{l_1^2} \quad \text{(II.18)}$$

$$(\boldsymbol{x} + \boldsymbol{r} - \boldsymbol{R})^{\mathbf{2}} + (\boldsymbol{y} - \boldsymbol{q_2})^{\mathbf{2}} = \boldsymbol{l_2^2} \quad \text{(II.19)}$$

Therefore, the reachable workspace of the reference point *O*' is the intersection of the sub-workspaces associated with the two kinematic chains as shown in Figure II.3

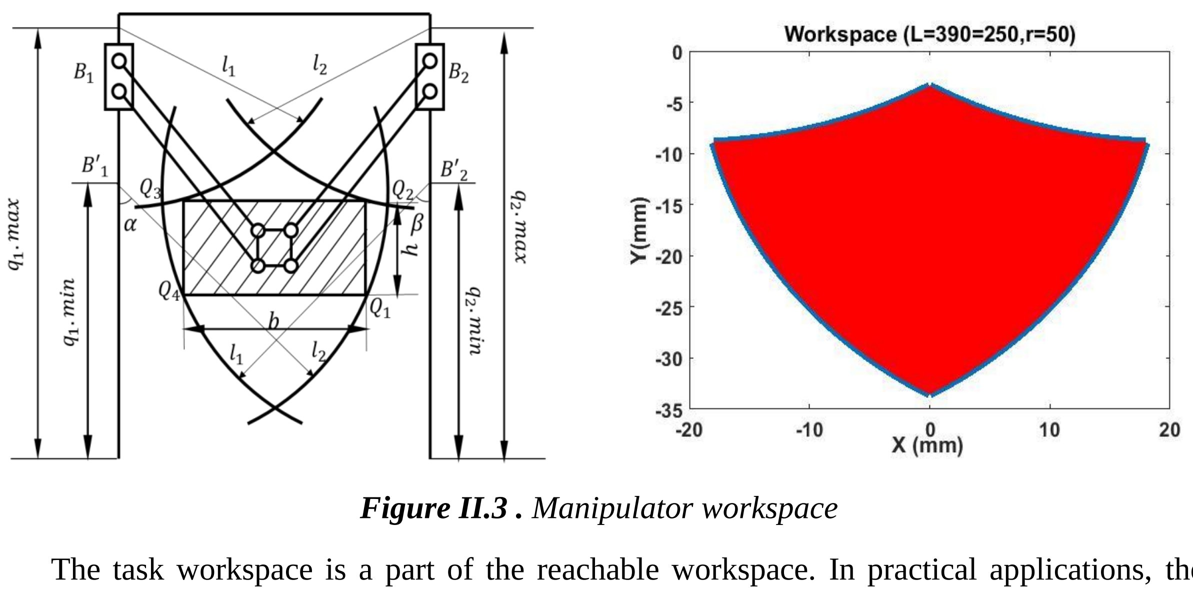


Figure II.3 . *Manipulator workspace*

The task workspace is a part of the reachable workspace. In practical applications, the task workspace is usually defined as a rectangular area in the reachable workspace.

Let the maximum limit of the angles α and β, which are the angles between link $A_i B_i$ (i = 1,2) and the vertical axis, be denoted by α_{max} and β_{max} . Let $q_{i\,max}$ and $q_{i\,min}$ represent the maximum and minimum positions of the i-th slider. O' reaches point Q_1 when slider B_1 reaches its lower limit and the value of α is the maximum, namely $q_1 = q_{1,min}$ and $\alpha = \alpha_{max}$. Similarly, O' reaches point Q_4 when $q_2 = q_{2,min}$ and $\beta = \beta_{max}$.

A vertical line through Q_1 intersects with the upper bound of the reachable workspace at point Q_2. Q_3 is directly above Q_4 (see Figure II.3). The region Q_1 Q_2 Q_3 Q_4 then makes up the task workspace, as a rectangle of width b and height h , denoted by W_t.

II .5. Conclusion

In this chapter, we present applications of parallel architectural robotics in the field of robotics. Our choice over a parallel robot was two degrees of freedom (planar parallel manipulators with 2'DOF). Also, we have modeled the general structure of the robot, and finally we will work to define the parameters in the next chapter.

Chapter III : Optimization of planar parallel manipulators with 2'DOF

Chapter III: Optimization of planar parallel manipulators with 2'DOF

III .1. Introduction :

After studying the general theoretical study of the parallel robot, we came to a practical studying. In this chapter, the optimization problem will be formulated in order to find the optimum dimensions of the studied robot by using Matlab simulation software to extract the necessary results.

III 1.1. Workspace evaluation :

The workspace is one of the most important kinematic properties of manipulators, even by practical viewpoint because of its impact on manipulator design and location in a work cell [50] A general numerical evaluation of the workspace can be deduced by formulating a suitable binary representation of a cross-section in the task space. A cross-section can be obtained with a suitable scan of the computed reachable positions and orientations p, once the forward kinematic problem has been solved to give P as function of the kinematic input joint variables q. A binary matrix P_{ij} can be defined in the cross-section plane for a cross-section of the workspace as shown in Figure III.1.

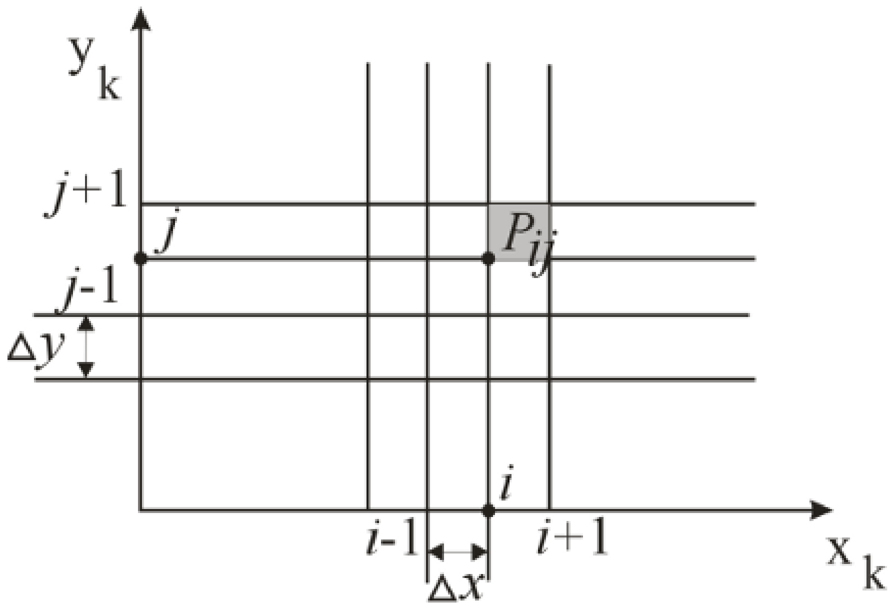


Figure III. 1. *The general scheme for binary representation and evaluation of robot workspace.*

In general, the parallel robots performances depend very much on their geometry, thus it became of great interest the optimization problems of parallel robots. A key aspect of the performances of the parallel robots is that they are very dependent on the topology and dimensioning of the robot. It became of a real interest for developing parallel robots for fulfilling the work tasks, thus introduction of the performance indices like or optimization criteria used to characterize the robot has become compulsory. In design of a robot, the workspace is of primary importance. Maximizing the workspace of the parallel robot is one of the main goals of the optimal design of parallel robots.

III .2. Optimization Process:

Optimization process in design is a tool of conceptualization and analysis used to achieve better designs or design improvements. It is a mathematical procedure for determining optimal solutions by representing all the complexities of the design in the form of design variable(s), objectives function(s) and/or constraint(s).

The basic elements of any constrained optimization problem are:

III .2.1. Objective function:

An objective function or vector of objective functions is the mathematical expression that expresses the optimization goal in terms of design variables. Optimization process is required to either minimize or maximize the objective function. For instance, in robotics, maximization of the workspace or minimization of inertia/mass of a manipulator can be the objective functions.

III .2.2. Design variables:

Also known as decision variables, are the "unknowns" of the optimization problem which are to be determined. From the point of view of the designer, these are the controllable numeric values which affect the value of the objective function. Design variables can be continuous (such as a length/diameter/cross-section of the robot links) or discrete (such as the number of links/joints in a robot).

III .2.3. Constraints:

A set of constraints that must be satisfied in order for the design to be feasible. These are mathematical expressions that combine the variables to express limits on the possible solutions. Constraints allow the design variables to take certain values but exclude others. In addition to physical laws; constraints can reflect resource limitations, user requirements, or bounds on the validity of the analysis models.

III .2.4. Variable bounds:

Design variables are not usually permitted to take any value. Instead, these are usually have lower and upper limits, known as variable bounds. Variable bounds limits the design space and along with constraints, used to distinguish the solutions as feasible or unfeasible.
The optimization problem is then:

Find the values of the design variables that minimize or maximize the objective function while satisfying the constraints. Remembering that variables describe all situations and constraints describe all feasible situations Mathematically, an single-objective optimization problem can be expressed as:

$$\min_x f \text{ subject to: } \begin{cases} g_i(x) \leq 0 & i = 1, \ldots . m \\ h_j(x) = 0 & j = 1, \ldots . n \\ x_l \leq x \leq x_u \end{cases} \quad \text{(III.20)}$$

Where, x is the vector of design variables, f is the objective function to be minimized subject to m inequality and n equality constraints given by $g_i(x)$ and $h_j(x)$, respectively.

Optimization is an iterative process and involves at least some degree of trial and errors. As the problem complexity is increased, the search procedure becomes tedious and may not guarantee a solution in all cases.

The main steps involved in solving an optimization problem can be cited as:

- understand the problem, by drawing a diagram or flow chart which represents the problem.
- write a problem formulation in words, including decision variables, objective function, and constraints.
- write the algebraic formulation of the problem.
  - define the decision variables.
  - write the objective function(s).
  - write the constraints.
- develop a spread sheet model.
- set up the Solver settings and solve the problem.
- examine the results and make corrections to the model.
- analyse and interpret the results.

III .2.5. Optimization method (A genetic algorithm (GA)) :

A genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. And they are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover. Genetic algorithms have been used to find optimal solutions to complex problems in various domains such as biology, engineering, computer science, and social science[51]

Genetic programming is a way of evolving algorithms that will map data to a given result when no set formula is known. Mathematicians/programmers can easily find algorithms to solve problems that deal with 5 or so variables [51].

III.2.5.1. Genetic algorithm methodology :

- **Initialization :**

At first huge numbers individual results need aid haphazardly created to structure a starting number. Those populace span relies on the way of the problem, in any case commonly holds a few hundred or many workable results. Traditionally, the populace may be produced randomly, coating those whole extend for could be allowed results (the hunt space). Occasionally, those results might a chance to be "seeded" On regions the place ideal results are inclined to make discovered[51].

- **Selection :**

Throughout every progressive generation, an extent of the existing populace may be chose will breed another era. Singular results are chosen through a fitness-based process, the place fitter results (as measured Eventually Tom's perusing a wellness function) need aid normally less averse will be chose. Certain Choice strategies rate the wellness for each result Also preferentially select those best results. Different techniques rate best An arbitrary example of the population, Likewise this methodology might be extremely drawn out[51].

- **Reproduction (mutation) :**

The next step is to generate a second-generation population of solutions from those selected through genetic operators: crossover (also called recombination), and/or mutation.

- **Termination :**

This generational cycle is rehashed until an end condition has been reached [51]. Basic ending conditions are:

- A solution is found that satisfies minimum criteria.
- Fixed number of generations reached.
- Allocated budget (computation time/money) reached.
- The highest-ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results.
- Manual inspection.
- Combinations of the above.

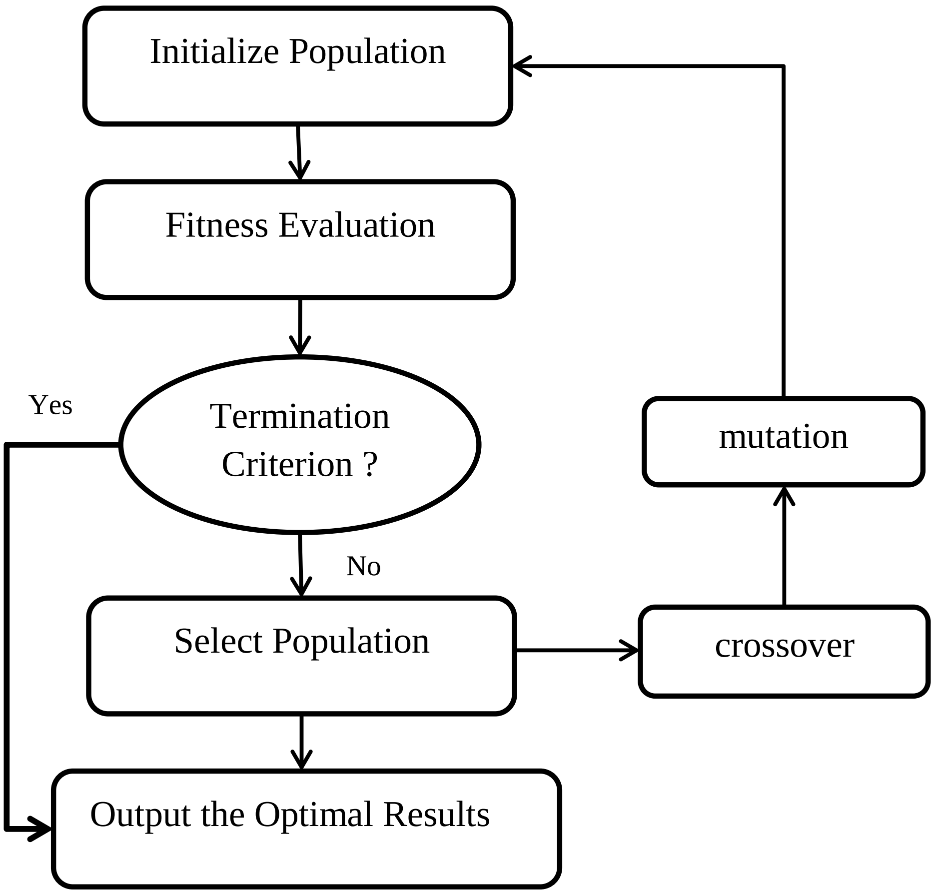


Figure III. 2. *diagram representation of genetic algorithms (GAs).*

III.3. Case study: Mono-Objective Design Optimization of a 2 DOF Planar Parallel Manipulator:

Planar parallel manipulators (PPMs) are distinguished by the feature that all their components and corresponding motions, including end-effector, generate planar motions. These mechanisms are simple with their simple kinematics and control-loop. Their obvious demerit is their unsuitability to carry out a large payload whose the weight is normal to the plane of motion.

III .3.1 Objective function :

In numerical analysis, the condition number of a matrix is used to estimate the error generated in the solution of a linear system of equations by the error in the data[52]. Salisbury and Craig (1982) [53] are the pioneer to use the condition number of the Jacobian matrix to design mechanical fingers of the articulated hands. Later on, Angeles and Rojas (1987) [54] used it as a kinetostatic performance index of the robotic mechanical system and applied it to the design of a 2-dof spatial manipulator and a 2-dof spherical wrist. In terms of the Jacobian matrix of a robot manipulator, the condition number is an error amplifying factor of actuators affecting the accuracy of the Cartesian velocity of the end-effector [55].

According to Angeles [56] , for a Jacobian matrix J, whose all entries have the same units, condition number κ (J), based on the 2-norm, can be defined as the ratio of the largest σ_{max} to the smallest σ_{min} singular values of J, i.e.,

$$\mathbf{1} \le \boldsymbol{\kappa}(\boldsymbol{J}) = \frac{\boldsymbol{\sigma_{max}}}{\boldsymbol{\sigma_{min}}} \le \infty \qquad \text{(III.21)}$$

σ_{max} and σ_{min} can be determined by solving the characteristic equation

$$\mathbf{det}(\boldsymbol{\sigma}^{\mathbf{2}}\boldsymbol{I} - \boldsymbol{J}^{\boldsymbol{T}}\boldsymbol{J}) = \mathbf{0} \qquad \text{(III.22)}$$

where **I** denotes a unit matrix of order 2.

In general, the global performance index is used as a measure of performance in kinematic design, is

$$\overline{\boldsymbol{\eta}} = \frac{\int_{W_t} \boldsymbol{\kappa} \boldsymbol{dW}}{\int_{W_t} \boldsymbol{dW}} \qquad \text{(III.23)}$$

where κ is the condition number of Jacobian matrix. Because $\bar{\eta}$ is incapable of describing the deviation between the maximum and minimum values of κ .

III .3.2 Design Variables :

In our case we should to choose the values of three elements L, R and r as shown in Figure II .1

• Limit of the x of the workspace (mm):

$$X_{Wt} = \begin{cases} -150 \leq \boldsymbol{x}\ (mm) \leq 150 \\ -100 \leq \boldsymbol{y}\ (mm) \leq 100 \end{cases}$$

• Limits of design variables :

$$\mathbf{L_{min} < L = l_1 = l_2 < L_{max}}$$

$$\mathbf{300 < L < 400}$$

$$\mathbf{R_{min} < R < R_{max}}$$

$$\mathbf{100 < R < 250}$$

$$\mathbf{r_{min} < r < r_{max}}$$

$$\mathbf{50 < r < 100}$$

Table III.1. Genetic Algorithms Parameters

Genetic Parameters	Magnitude
Number of Generations	100
Population size	60
Mutation rate	0.005
Function Tolerance	1e-8
Crossover rate	0.08

Table III.1 shows Various Genetic Algorithm parameters taken up for the optimization of process controllers.

Based on all problem parameters, and the data relative to this robot. The use of the genetic algorithm under Matlab, gives us the presented graphical results which are presented in Figures (III.3 and III.4).

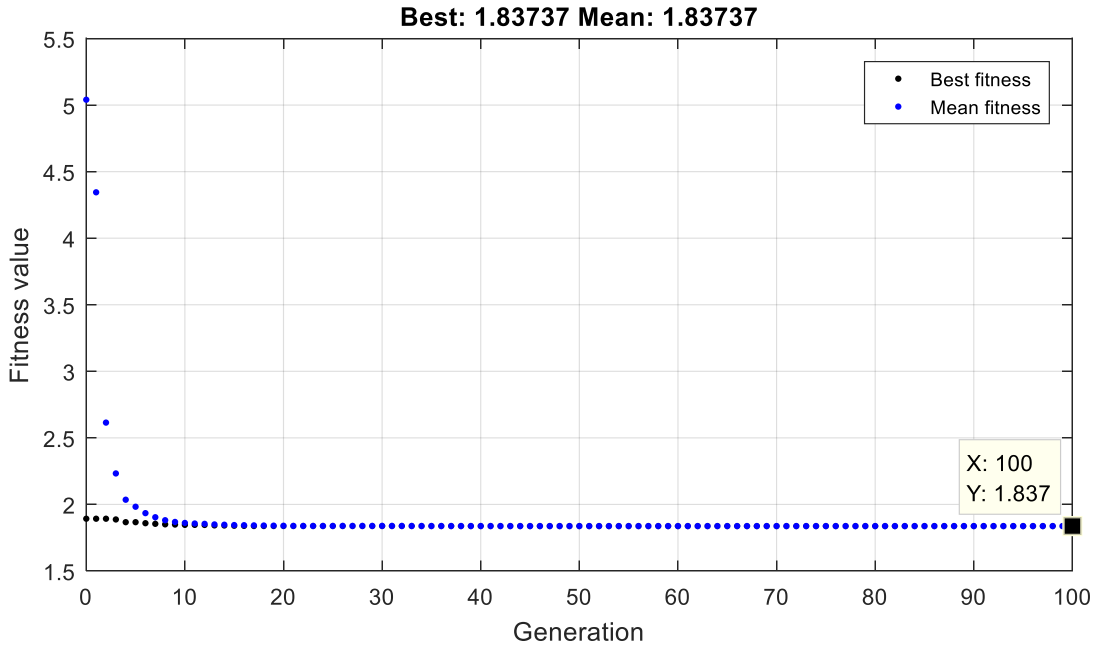


Figure III. 3. *Evolution of the objective function during the iterations.*

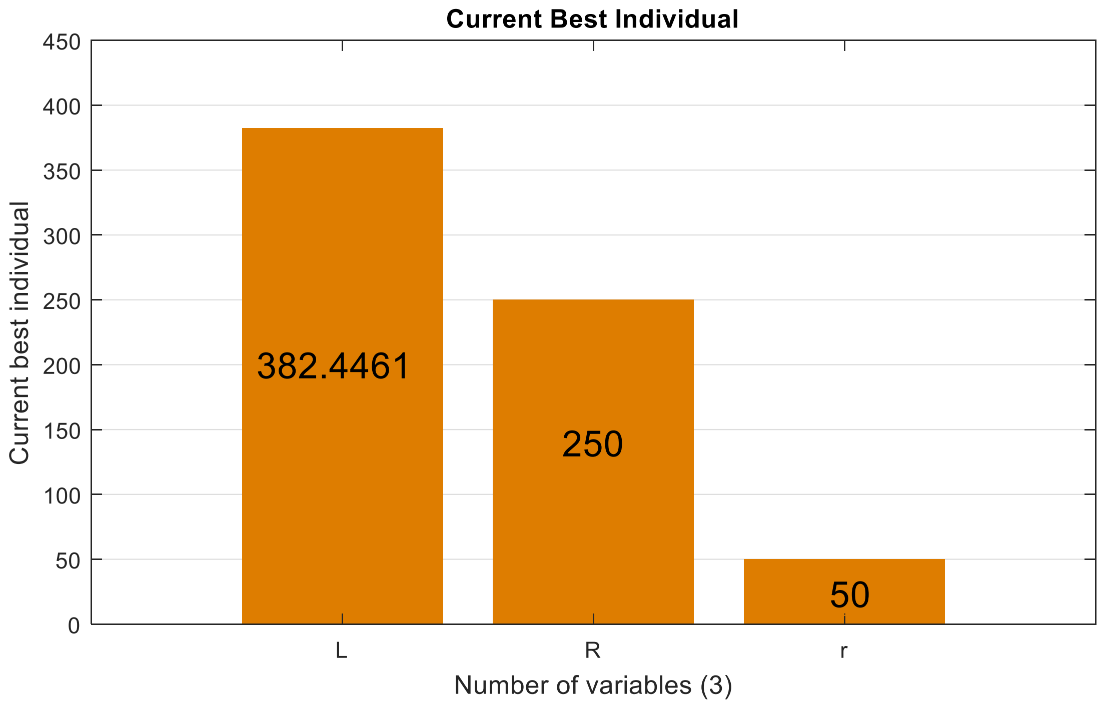


Figure III. 4. *Optimal individuals*

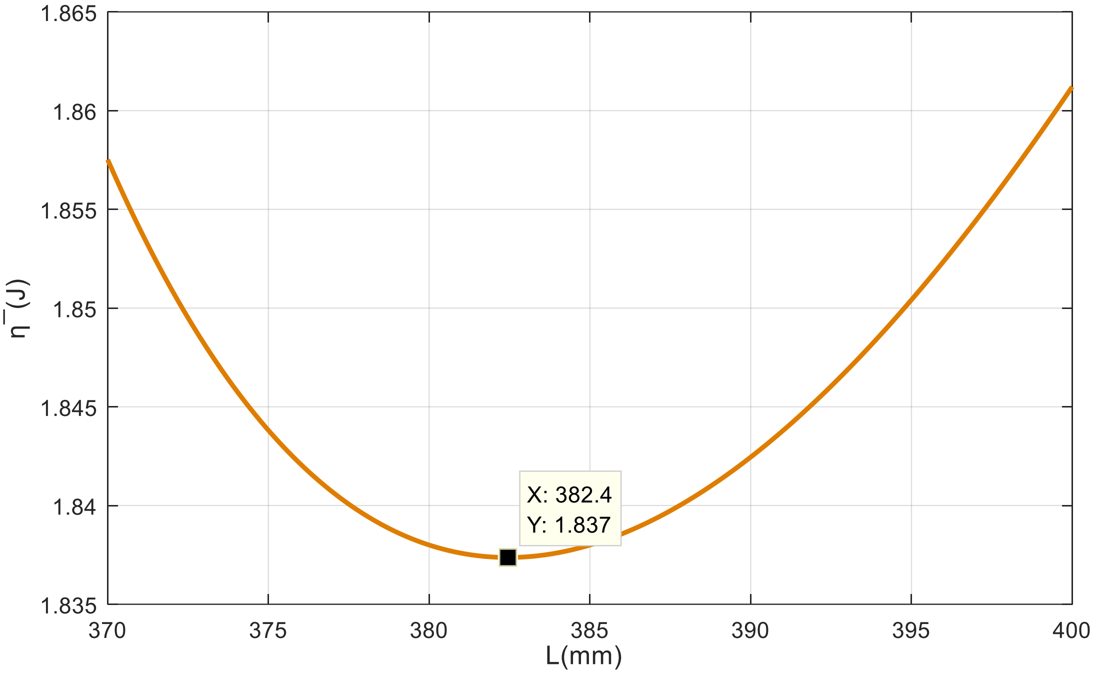


Figure III. 5. *Conditioning of the inverse Jacobian matrix as a function of L*

(R=250 ,r=50)

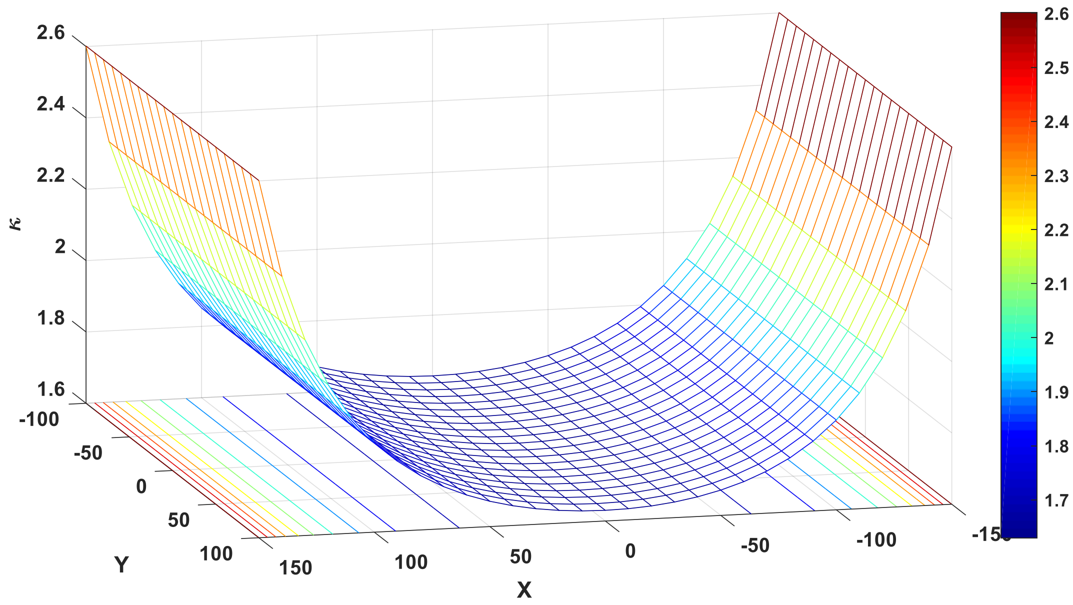


Figure III. 6. *Distribution of the condition number in workspace when* ***L*** *is specified.*

Optimizing our machine gives us the optimal dimensions (Table III.2) , that we will use in the next part.

Table III.2. Optimal solution obtained.

objective Fonction $\bar{\eta}$	**L** **(mm)**	**R** **(mm)**	**r** **(mm)**
1.8374	382.4461	250	50

III.4. Simulation of Inverse kinematics :

In this step, we chose a trajectory of mobile platform $[x\ y]$ using a subsystem "X_value" (show Figure 7), and the output are the positions[q_1,q_1,], speeds [V_{q1},V_{q2}] and accelerations [A_{q1},A_{q2}] of the actuators.

The parameters of simulation of Biglid robot are following:

Length of Links L= 382.4461 [mm]

Radius of Base R= 250 [mm]

Radius of mobile platform r= 50 [mm]

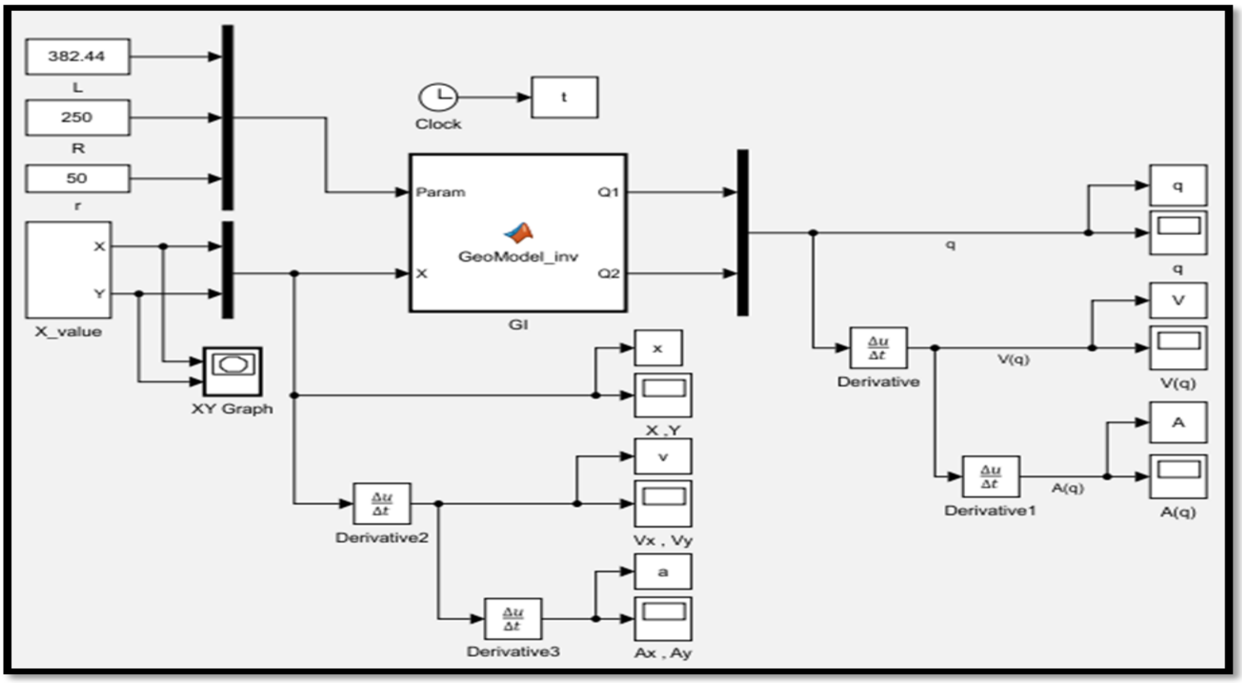


Figure III. 7. *The block of Simulation*

In our work, for verification of the model properties a mobile platform trajectory was programmed as a circle in the x-y plane with the period of 2π.

This trajectory is shown in Figure III.8.

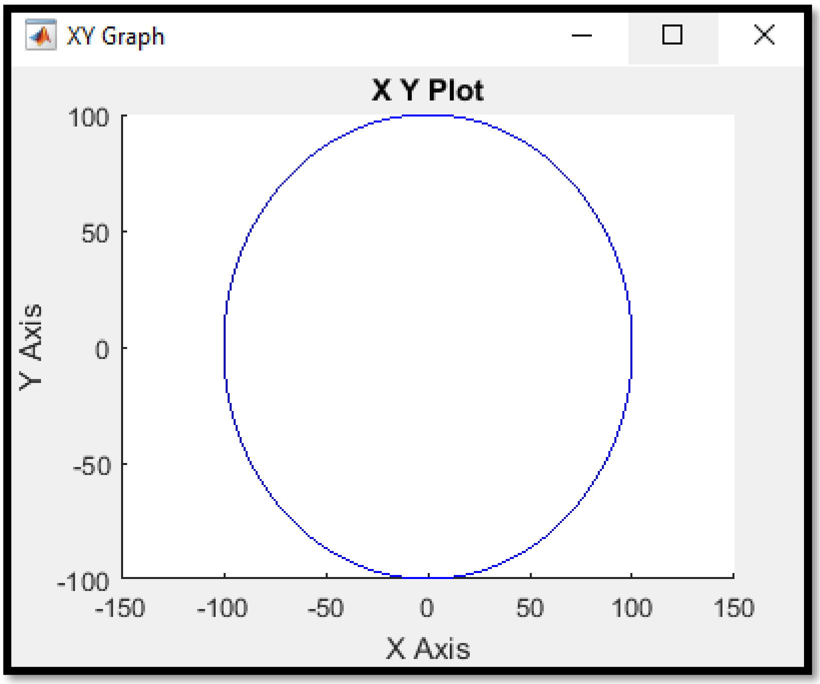


Figure III. 8. *Input and Output desired mobile platform Circle trajectory in the x-y plane*

III.4.1. Results of simulation:

The following figures show the displacements, the speeds, and the accelerations of the articular coordinates or the parameters of the motorized connections q following the trajectory chosen previously.

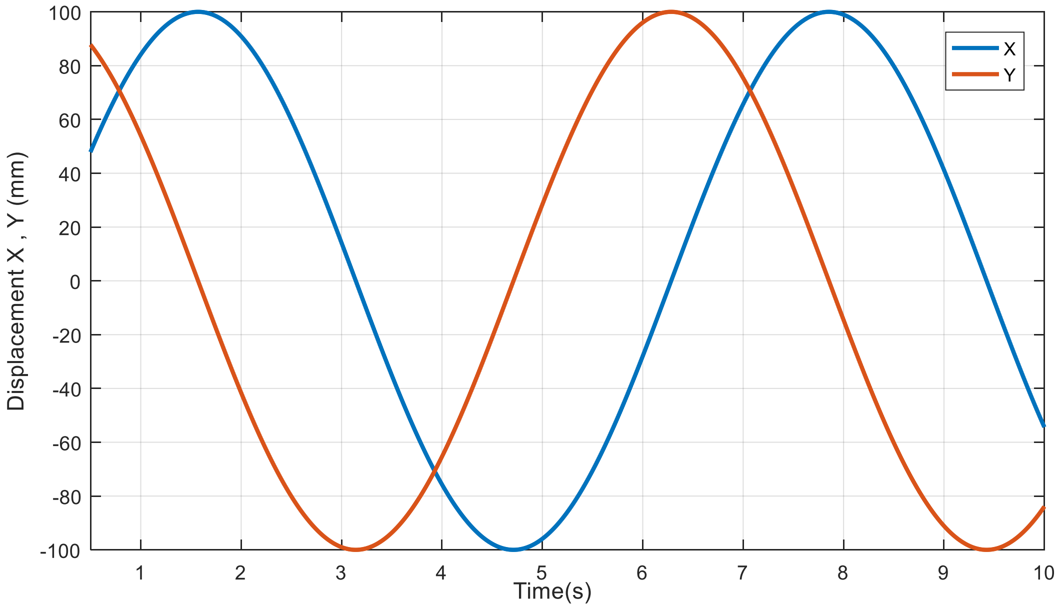


Figure III. 9. *The displacement curve (x , y).*

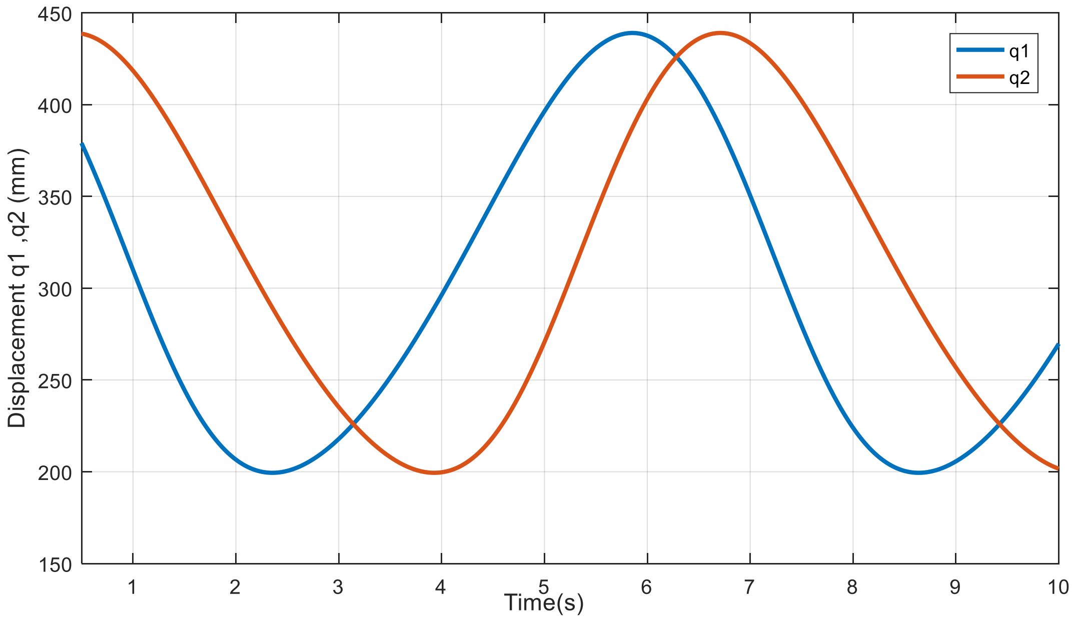


Figure III. 10. *The displacement curve (q_1 , q_2).*

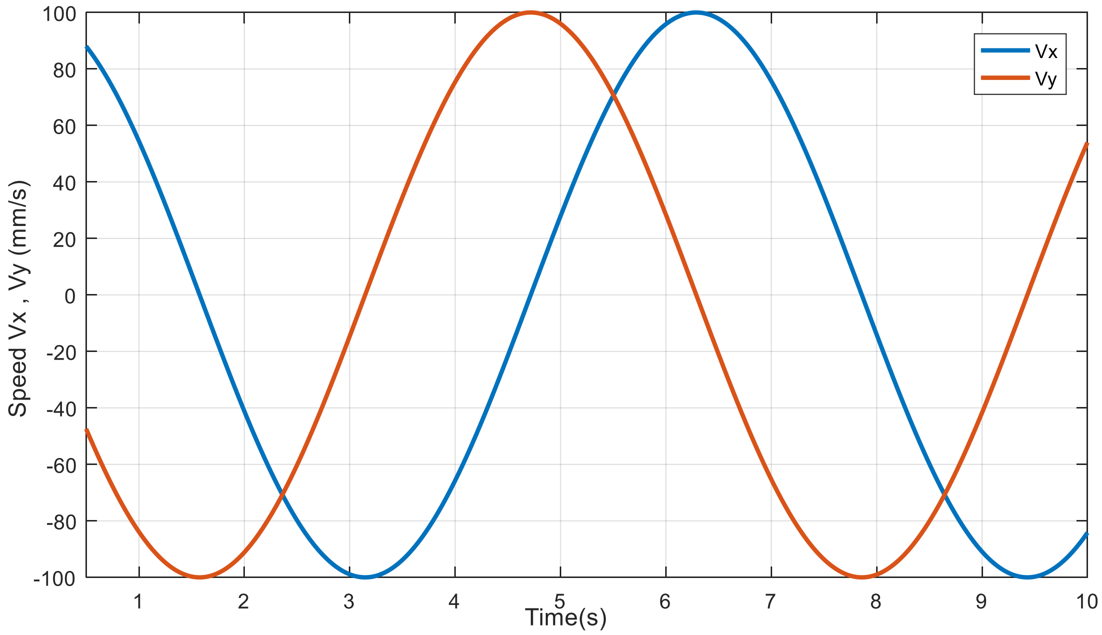


Figure III. 11. *The speed curve (V_x , V_y).*

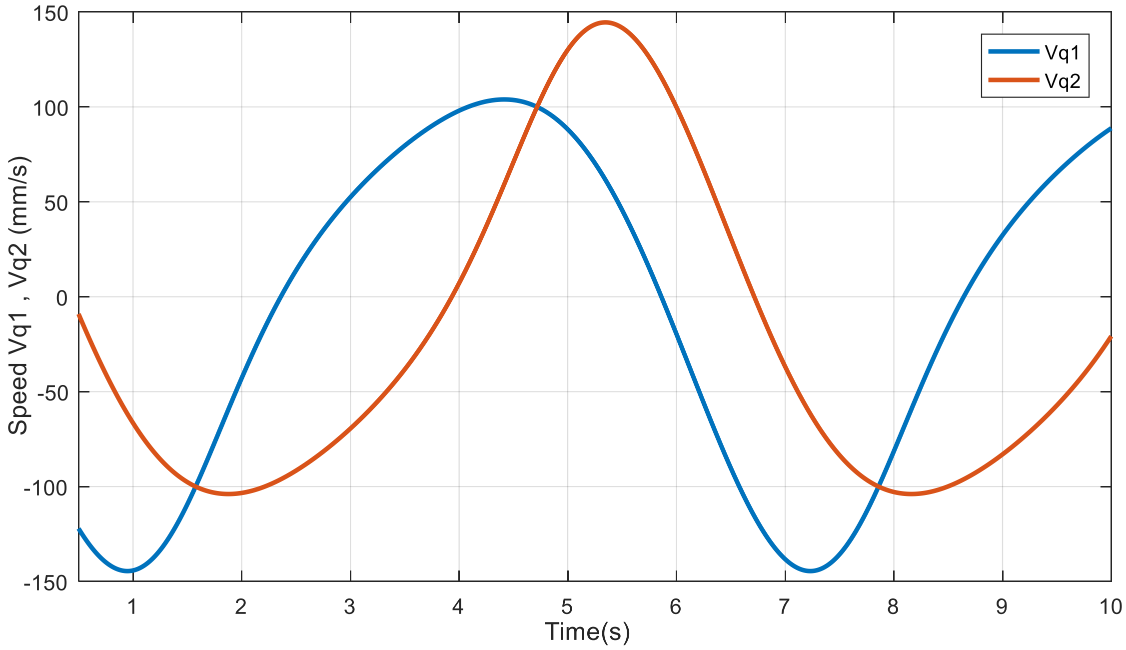


Figure III. 12. *The speed curve (V_{q1} , V_{q2}).*

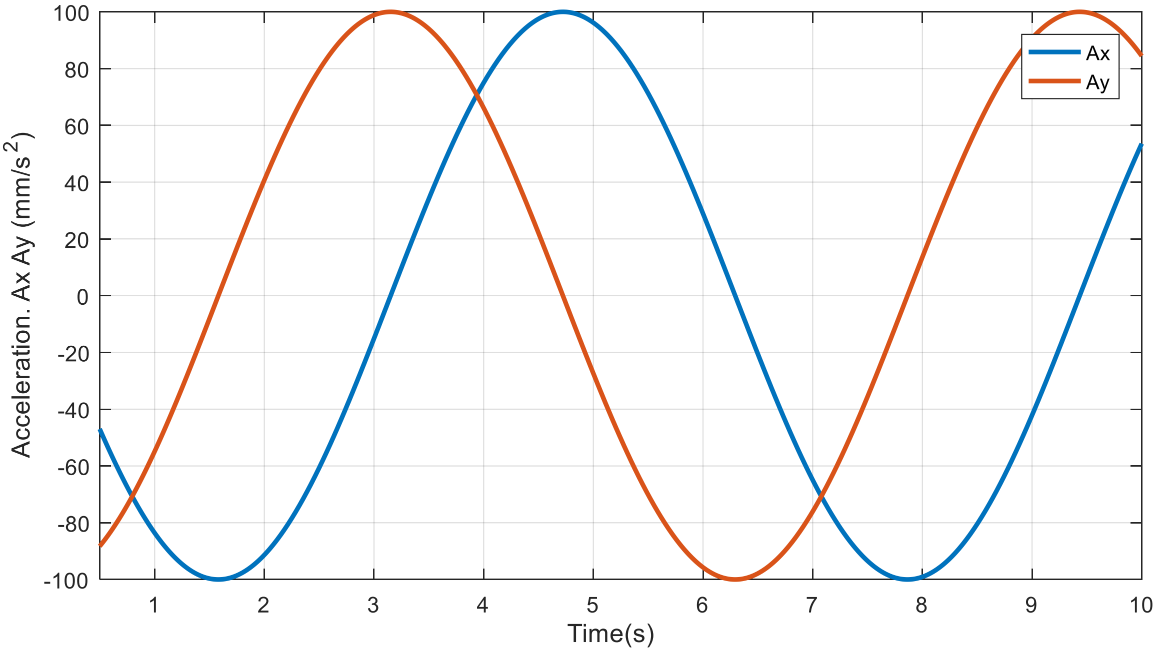


Figure III. 13. *The curve of the acceleration (A_x , A_y).*

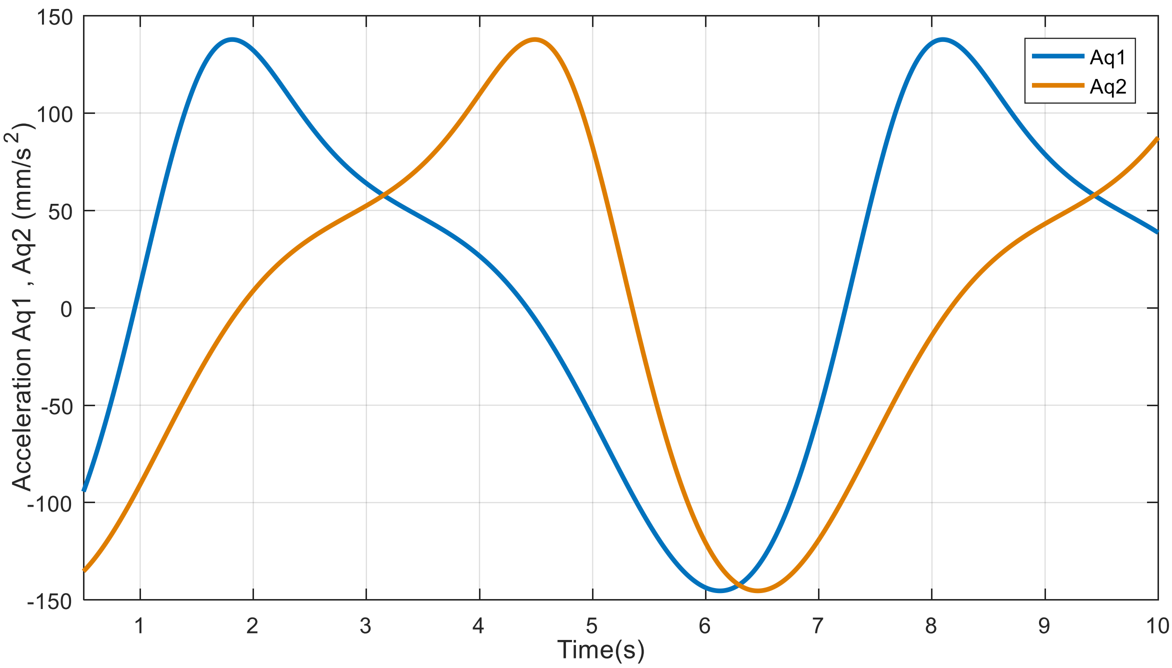


Figure III. 14. *The curve of the acceleration (A_{q1} , A_{q2}).*

III.5.Conclusion

The results show that GA can determine the architectural parameters of the robot that provide an optimized workspace. Since the workspace of a parallel robot is far from being intuitive, the method developed should be very useful as a design tool.

Based on the presented optimization methodology we can conclude that the optimum design and performance evaluation of the parallel robot is the key issue for an efficient use of parallel robots. This is a very complex task and in this work was proposed a framework for the optimum design considering basic of workspace.

The simulation results show the displacement changes, velocities and acceleration values with respect to the selected workspace and path.

General conclusion:

We have presented in this manuscript a methodology for the design and construction of complex systems, namely the design of parallel robots with 2 degrees of freedom (DOF).

The choice of the right parallel architecture is made after comparisons between the characteristics of series robots and parallel robots. Among these parallel architectures we take the Biglid architecture robot. Then, we chose the layout of our machine, in order to do a geometric, kinematic robot modeling.

In this work, we formed a problem of optimizing our machine. In this thesis, we have used the technique of the genetic algorithm (Matlab Toolbox) that we implemented in Matlab. We have an objective to optimize, concerns the kinematic isotropy with three decision variables. The results obtained show that there is an influence of the length of the robot bars on the objective function which is the conditioning of the Jacobian matrix. In the end we found an optimal solution for robot dimensions.

Genetic algorithms (GA) are so far generally the best and most robust kind of evolutionary algorithms. A GA has a number of advantages. It can quickly scan a vast solution set. Bad proposals do not affect the end solution negatively as they are simply discarded. The obtained results have shown that the use of GA in such kind of optimization problem enhances the quality of the optimization outcome, providing a better and more realistic support for the decision maker

Finally, we conclude with the following perspectives : to apply this study on different types of parallel robot, with an improvement and assurance of several measurement points and that the optimal kinematic parameters are achieved by using a global and comprehensive performance index to perform the kinematic optimal design.

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Annexes:

Notation of links in layout graphs

Layout graphics represent the topology of the robot structure and highlight the various branches and loops , They allow a better understanding of the sometimes subtle architecture of parallel mechanisms **,** They have been proposed by [31]. Table A.1 represents the symbolism used for these graphs.

On the other hand with this type of representation , information about the geometric arrangement of the links is lost.

Table A.1: *Symbols of layout graphs*.

Joint	Passive	Motorized	measured	Mobility
Prismatic (slide)	P	P	P	1(translation)
Rotoide (pivot)	R	R	R	1(rotation)
Universl (gimbal)	U	U	U	2(rotation)
Spherical(ball joint)	S	S	S	3(rotation)
Other robot component				
Built(based)				
Terminal organe (nacelle)				
Room				

Abstract:

Report title: Optimal design of a planar parallel robot at 2DoF.

Key words: Parallel Robot, Robot with 2 DOF, Geometric and Kinematic Model.

Abstract:

This memory focuses on optimization the conception (design) of a parallel planar robot with two degrees of freedom (2 DOF), and we have chosen the Biglid robot in this work. This work includes the geometric and kinematic study of the chosen robot, and this step is important given that the performance standards for a particular structure depend heavily on the dimensions of this structure, and then we were interested in studying the problem of optimizing the workspace of the selected structure with the help of the genetic algorithm (GA), which showed its success in this field in terms that are so far generally the best and most robust kind of evolutionary algorithms. A GA has a number of advantages. It can quickly scan a vast solution set.
We concluded the work by simulating the robot and the conditions that were previously set before starting the optimization experiments, by using Matlab software.

Titre du mémoire : Conception Optimal d'un Robot parallèle planaires à 2ddl.

Master : Electromécanique

Mots clefs : Robot Parallèle, Robot de 2 ddl, Modèle géométrique et cinématique.

Résumé :

Cette mémoire se concentre sur l'optimisation de la conception d'un robot planaire parallèle à deux degrés de liberté (2 ddl), et nous avons choisi le robot Biglid dans ce travail. Ce travail comprend l'étude géométrique et cinématique du robot choisi, et cette étape est importante étant donné que les normes de performance pour une structure particulière dépendent fortement des dimensions de cette structure, puis nous nous sommes intéressés à étudier le problème de l'optimisation de l'espace de travail de la structure choisie à l'aide de l'algorithme génétique (GA), qui a montré son succès dans ce domaine en termes qui sont jusqu'à présent généralement le type d'algorithme évolutif le meilleur et le plus robuste. Une GA présente de nombreux avantages. Il peut analyser rapidement un vaste ensemble de solutions.

Nous avons conclu le travail en simulant le robot et les conditions précédemment fixées avant de démarrer les expériences d'optimisation, en utilisant le logiciel Matlab.

عنوان المذكرة: التصميم الأمثل للروبوت المتوازي المستوي مع 2 درجة من الحرية.

الكلمات المفتاحية: روبوت المتوازي، روبوت مع 2 درجة من الحرية، نموذج هندسي وحركي.

ملخص:

تركز هذه المذكرة على تحسين تصميم روبوت مستوٍ متوازي بدرجتين من الحرية (2 DOF)، وقد اخترنا في هذا العمل روبوت ثنائي الإنزلاق Biglid (محركان خطيان) ، يشمل هذا العمل الدراسة الهندسية والحركية للروبوت المختار، وهذه الخطوة مهمة بالنظر إلى أن معايير الأداء لهيكل معين تعتمد بشكل كبير على أبعاد هذه البنية، ومن ثم اهتممنا بدراسة مشكلة تحسين مساحة عمل الهيكل المختار بمساعدة الخوارزمية الجينية (GA)، والتي أظهرت نجاحها في هذا المجال من حيث انها حتى الآن أفضل أنواع الخوارزميات التطورية وأكثرها قوة. تمتلك GA عدداً من المزايا، يمكنه مسح مجموعة حلول واسعة النطاق بسرعة.

اختتمنا العمل بمحاكاة الروبوت والظروف التي تم ضبطها مسبقاً قبل بدء تجارب التحسين، باستخدام برنامج Matlab.