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MODELING WORKSPACE OF PLANAR PARALLEL KINEMATICS MACHINES WITH 2 DEGREES OF FREEDOM[1]

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In the modern industry time plays a very important role. It's the time that determines how quickly your company can produce something and give necessary service.

Nowadays modern industry try's to automates the most part of the industrial processes. However it is not always possible because of type of the applied equipment. The mechanical structure of today's machine tools is based on serial kinematics in the overwhelming majority of cases. The modern life dictates it's our conditions. In modern industry new equipment appears and it's based on parallel kinematics. But there are some difficult while use it.

If we want to build our own delta robot, we need to solve two problems. First, if we know the desired position of the end effector (for example, we want to catch pancake in the point with coordinates X, Y, Z), we need to determine the corresponding angles of each of three arms (joint angles) to set motors (and, thereby, the end effector) in proper position for picking. The process of such determining is known as inverse kinematics.

And, in the second place, if we know joint angles (for example, we've read the values of motor encoders), we need to determine the position of the end effector (e.g. to make some corrections of its current position). This is forward kinematics problem [1].

To be more formal, let's look at the kinematic scheme of delta robot. The platforms are two equilateral triangles: the fixed one with motors, and the moving one with the end effector.

While designing such equipments it's necessary to know characteristics of the workspace of manipulators for giving limits for the size of driving mechanism. As a rule a workspace of such devises represents there are complicated geometrical figure [2]. To show a workspace it was offer to divide manipulators into several two-coordinators. It's not difficult to find parameters of the workspace solving this problem of visualization from this point. The workspace of manipulators can be found by fixation of every devises at minimal and maximal length in turns. As we can see research of workspace of complicated manipulators reduce to a minimum.

The workspace of a robot is defined as the set of all end-effector configurations which can be reached by some choice of joint coordinates. As the reachable locations of an end-effector are dependent on its orientation, a complete representation of the workspace should be embedded in a 6-dimensional workspace for which there is no possible graphical illustration; only subsets of the workspace may therefore be represented.

There are similar simplest mechanism in the family of parallel kinematics machines. Research of such family will allow engineers to work out criteria to making mechanism at the stage of modeling.

The workspace is one of the most important kinematics properties of manipulators, even by practical viewpoint because of its impact on manipulator design and location in a work cell (Ceccarelli et al., 2005). Workspace is a significant design criterion for describing the kinematics performance of parallel robots. The planar parallel robots use area to evaluate the workspace ability. However, is hard to find a general approach for identification of the workspace boundaries of the parallel robots. This is due to the fact that there is not a closed form solution for the direct kinematics of these parallel robots. That's why instead of developing a complex algorithm for identification of the boundaries of the workspace, it's developed a general visualization method of the workspace for its analysis and its design.

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It is crucial to calculate the workspace and its boundaries with perfect precision, because they influence the dimensional design, the manipulator's positioning in the work environment, and its dexterity to execute tasks.

A planar Parallel Kinematics Machines is formed [3] when two or more planar kinematic chains act together on a common rigid platform. The most common planar parallel architecture is composed of two chains (Fig. 1), where the notation denotes the planar chain made up of a revolute joint, a prismatic joint, and a second revolute joint in series .

There are a wide range of parallel robots that have been developed but they can be divided into two main groups [3; 7, p.206]:

– Type 1) Parallel Kinematics Machine with variable length struts;
– Type 2) Parallel Kinematics Machine with constant length struts.

Since mobility of these Parallel Kinematics Machines is two, two actuators are required to control these Parallel Kinematics Machines. For simplicity, the origin of the fixed base frame {B} is located at base joint A with its x-axis towards base joint B, as shown in Fig. 2. The distance between two base joints is *b*. The position is $x = (x_p; y_p)^T$ and the actuated joint variables are represented by $q = (q_1; q_2)^T$ [4, p.12].

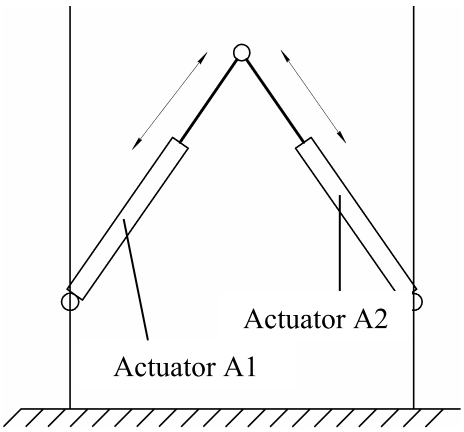


Fig. 1 Variable length struts Parallel Kinematics Machine [4: p.14, fig.16]

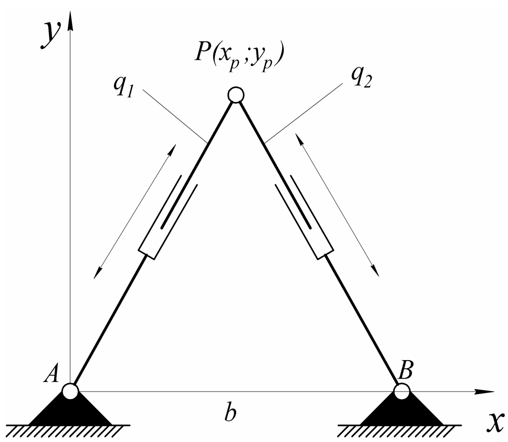


Fig. 2 The general kinematic scheme of a Parallel Kinematics Machine [4: p.6, fig.10]

The workspace of the 2 DOF planar PKM of type Bipod is often represented as a region of the plane, which can be obtained by the reachable points P (fig. 3). Such solving can be received in coming case when we have inequality $L < b/2$.

The following presents the main factors affecting workspace. For ease of comparison a cubic working envelope with a common contour length is used together with a machine size that is calculated from the maximum required strut length.

The working envelope to machine size using variable length struts is dependent on the following factors [4, p.7]:

1. The length of the extended and retracted actuator (Lmin, Lmax);
2. Limitations due to the joint angle range.

The limiting effect of the joint limits is clearly illustrated in Fig. 4.

It's very important to analyze the area and the shape of workspace for parameters given robot in the context of industrial application. The workspace is primarily limited by the boundary of solvability of inverse kinematics. Then the workspace is limited by the reachable extent of drives and joints, occurrence of singularities and by the link and platform collisions. Analysis, visualization of workspace is an important aspect of performance analysis. A numerical algorithm to generate reachable workspace of parallel manipulators is introduced (Fig. 5a, 5b, 5c) [4].

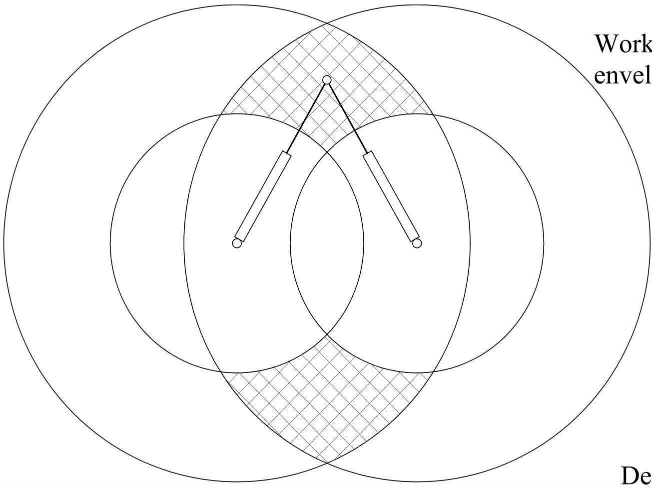


Fig. 3. The workspace is the intersection of two enveloping surface of two legs [3; 6: fig.4]

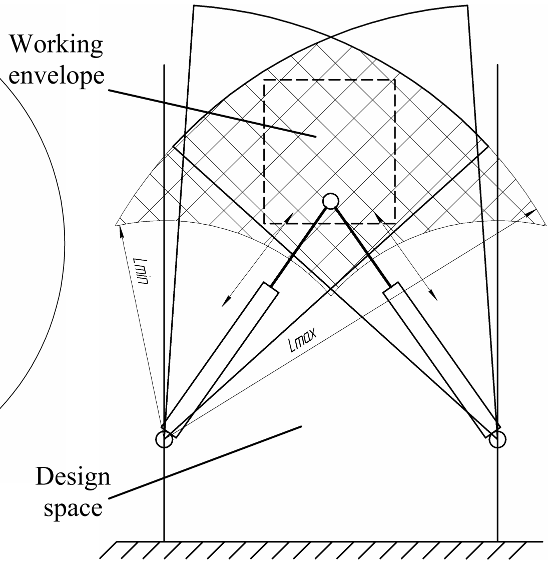
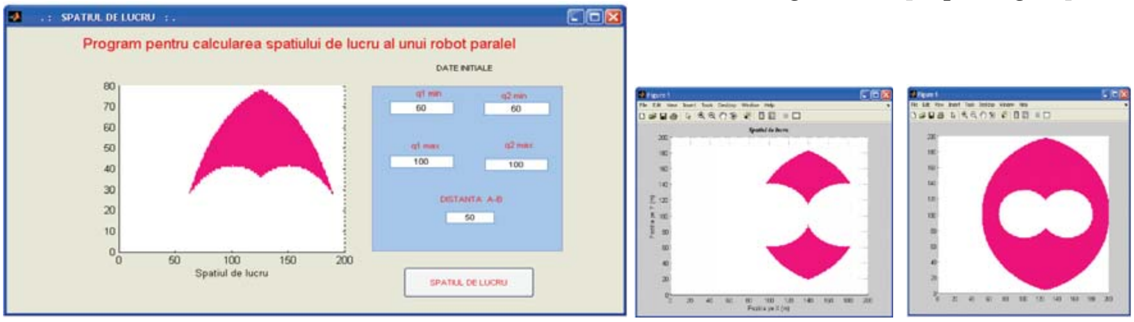


Fig. 4. Workspace of the Parallel Kinematics Machine with variable length struts [4: p.7, fig.11]

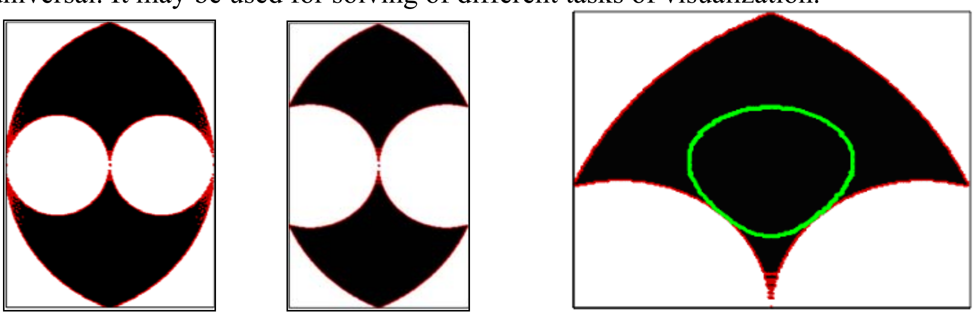


a) b) c)

Fig. 5. The GUI for calculus of workspace for the planar 2 DOF Parallel Kinematics Machine with variable length struts [4: p.9, fig.13; p.10, fig.17; p.12, fig13]

However this algorithm is uncompleted. The author had been developed other algorithm [5] of visualization in program MathCAD (Fig. 6 a, b). It can do all the same as analogue. But it can also to show working space for a task solution with known parameters (Fig. 6 c). And it is very important component for the subsequent analysis.

Thus the algorithm given by the author allows to depict the necessary field of moving (as green line, fig. 6 c). On a level with the standing solving of the problem of visualization of workspace (fig. 6 a, b). In contradistinction to algorithm [3] this algorithm has free code and it's more universal. It may be used for solving of different tasks of visualization.



a) b) c)

Fig. 6. The workspace of the planar 2 DOF Parallel Kinematics Machine is shown as the shading region.

Example. A(-2; 0), B(2; 0), Lmin = 2, Lmax = 5. Let working space will be limited to action actuator A1 and A2 (fig.1) L = 3, and the size of a course ΔL = 1.

Then we will receive the image (fig. 7). The allocated region from a working space just also shows the example decision.

Having such instrument of modeling it is possible to pick up executive mechanisms (actuators) correctly. As it is possible to see behavior of the mechanism in exceptional positions or special zone.

One more advantage of the created algorithm - that it is opened. It allows the engineer most to change it for the decision of his own problems.

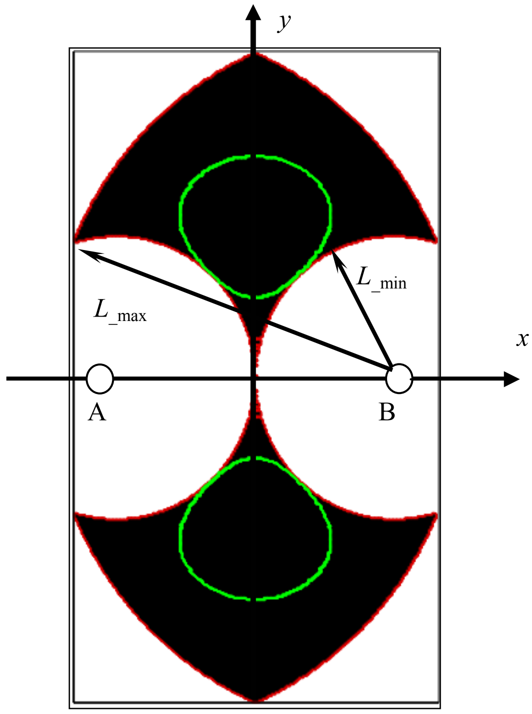


Fig. 7. Example of work of the developed algorithm of visualization.

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