# Working drawing from a minipulator arm with 6 DOF



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# WORKSPACE DRAWING FROM A MANIPULATOR ARM WITH 6 DOF

***Abstract:*** *Modelling and simulation is an important aspect in robotic field. Knowing of the workspace is very important to the operation of manipulators arm. This paper investigates operational performance of space manipulator arm destined for industrial manufacturing, by defining and analyzing their workspace and manipulability measure. The authors show that manipulator arm developing requires the consideration of more efficient dynamic models and use of dedicated processing techniques such as Autodesk-Inventor 9, MATLAB, WorkSpace software.*

***Key words:*** *manipulator arm, design, CAD, workspace analysis.*

## 1. INTRODUCTION

The industrial area has become an important application field of robotics.

Today, special purpose automated machines, designed to perform specific functions in a working process, carry out most of industrial manufacturing.

Many technological operations can be substitute in working process through implication of the manipulator arms.

The manipulator arm presented in this paper can serve a robotic assistant developed for manufacturing and assembly tasks, such as material handling, spot/arc welding, parts assembly, spray painting etc.

Constructively, a robot is made up of two main parts [3]:

- *manipulator*: part of the robot that consists of a sequence of rigid bodies, called links, connected by either revolute or prismatic joints. Each joint-link pair constitutes one degree of freedom (DOF);
- *controller:* contains the electronics required to control the manipulator.

The process of developing mechanical's part of the manipulator can be a laborious work due to the difficulties testing prototypes in real life situations.

In our days, for engineers, using of the virtual reality for designing and analyzing of the mechanical equipments becomes indispensable. With help of graphical software, the engineers can create an extensive variety of scenarios for a specific model and concrete situations.

## 2. BACKGROUNDS

For development of the virtual model of the manipulator arm RRRRRR proposed in this paper it was used followings steps:

- for designing and initial analysis: *Autodesk-Inventor 9©*;
- for physico-mathematic model of the mechanical structure: *SimMechanics©*;
- for physic-mathematic model of the hydraulic drive system: *SimHydraulics©*;
- for complete modeling of the ensemble: *Simulink/SimScape©*;
- for results processing and analysis: *Matlab 2007b©*.

It is known that *SimMechanics©*, *SimHydraulics©*, *SimScape©* represent the sub-blocks into *Simulink©,* which is a specialized component from graphical programming for the applications on software engineering *Matlab©.*

In addition, the elaboration of maximal area of the spatial evolution of the manipulator arm was made with *WorkSpace 5©* produced by WAT Solutions from USA.

## 3. DESIGN REQUIREMENTS FROM CAD MODEL

The first stage of virtual modeling concept of manipulator arm is based consists on structure designing with CAD techniques [1], [5]. The benefits of this stage consist on the next aspects:

- directly visualization of the structural configuration of mechanical parts of manipulator arm;
- facile kinematics estimation of entire mechanism;
- structural and kinematics nonconformity verification for evaluation of value domains and constraints for geometric and cinematic parameters;
- mass evaluation, of the weight center coordinates and of the inertial torque for each component and for entire mechanical system;
- obtaining of the models on STL format (*STereo-Lithography*) needed in the final stage of cinematic and dynamic physico-mathematic modeling – virtual analysis in *SimMechanics* or *VirtualReality*;
- obtaining of the SAT model of the manipulator arm used in behavior analysis with help of *WorkSpace 5* software.

After optimization process from kinematics point of view, the authors was established the final shape of all components of the manipulator arm, shown in the fig. 1.

The material properties in the design of the manipulator arm will determine largely its reaction under working condition.

We have chosen materials that make the structure be strong under the application of loads and witch will develop continuous amounts of stress.

Thus, all the seven main structural components it was designing from aluminium (cod 6061 – into *Inventor Software*) with 2.710 $10^{-006}$ kg/mm$^3$ density.

After modeling phase we can attach it to the assembly for obtaining of the six rotations serial manipulator's arm, presented in the figure 2.

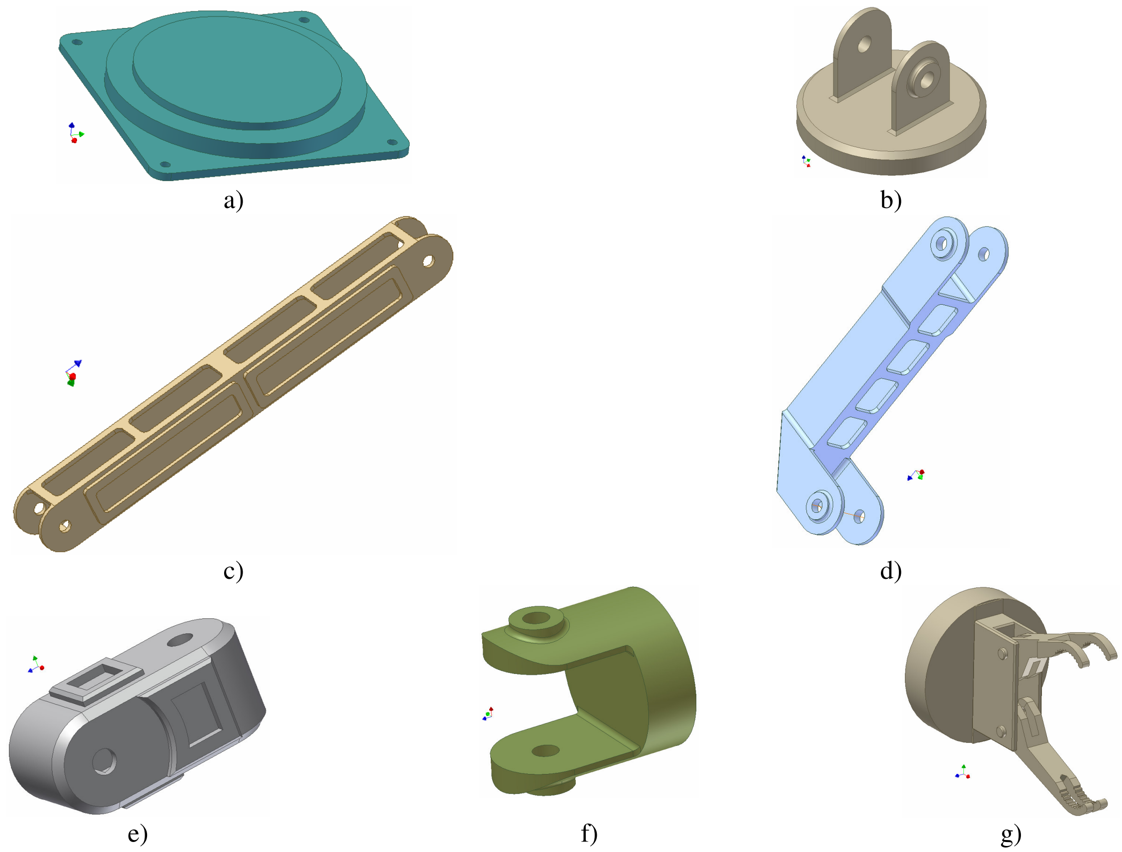



**Fig.1** The main structural elements of the manipulator arm with 6 DOF.
a) fixing system; b) platform; c) coupling element; d) port-hand element; e) main arm; f) boom arm; g) end-effector with prehension system.

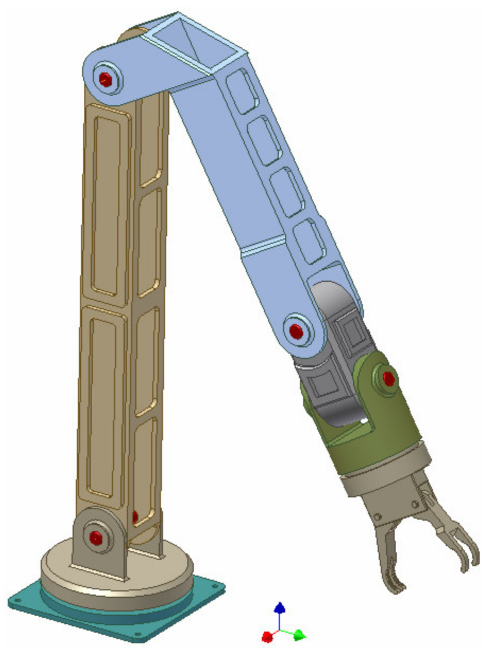


**Fig. 2** Ensemble view of the manipulator.

## 4. GRAPHICAL REPRESENTATION OF THE WORKING SPACE FOR MANIPULATOR ARM

The space curve that the manipulator hand moves along from an initial location (position and orientation) to the final location is called the robot path [2].

In our case, the linkage between the integral model madden in *Autodesk - Inventor 9©* and *WorkSpace 5©* was realized through SAT standard for graphic files.

Thus, the manipulator will be imported in *WorkSpace 5©* software and will bring out such in the figure 3.

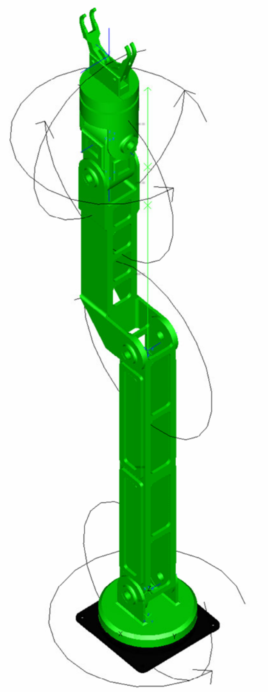


**Fig. 3** SAT model of the manipulator arm with 6R.

Into *WorkSpace* informatics medium there are possibilities to evaluate of the maximal kinematics capacity of the manipulator's arm for two situations [6]:

a) based on the first DOF - this thing is useful due these three independent coordinates concur at prehension system positioning into the operation area over the object which must be manipulate;

b) based on two DOF chose independently by the engineer from available list, for analyzed equipment; these evaluations offer the users information about working potential capacity of each element and each joint from manipulator's structure. In this way, the cinematic ambiguities, impossibility of motion or due insufficient operation space are avoided [4].

For the first working situation, according to the first three DOF (GdM), the evaluation's result is presented in the figure 4.

If we taking the combination between these six DOF of manipulator's, in the figure 5 the respective evaluation results it's obtained. For conformity, we note $GdM_{i-j}$ for situation that *i* is the first DOF and *j* is the second DOF.

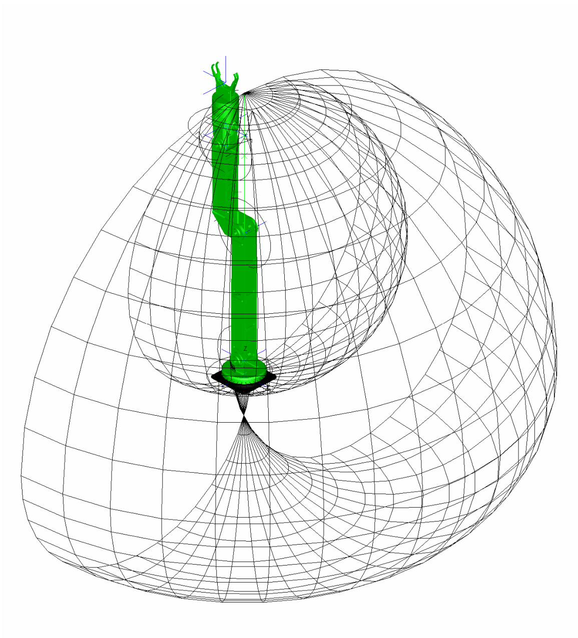
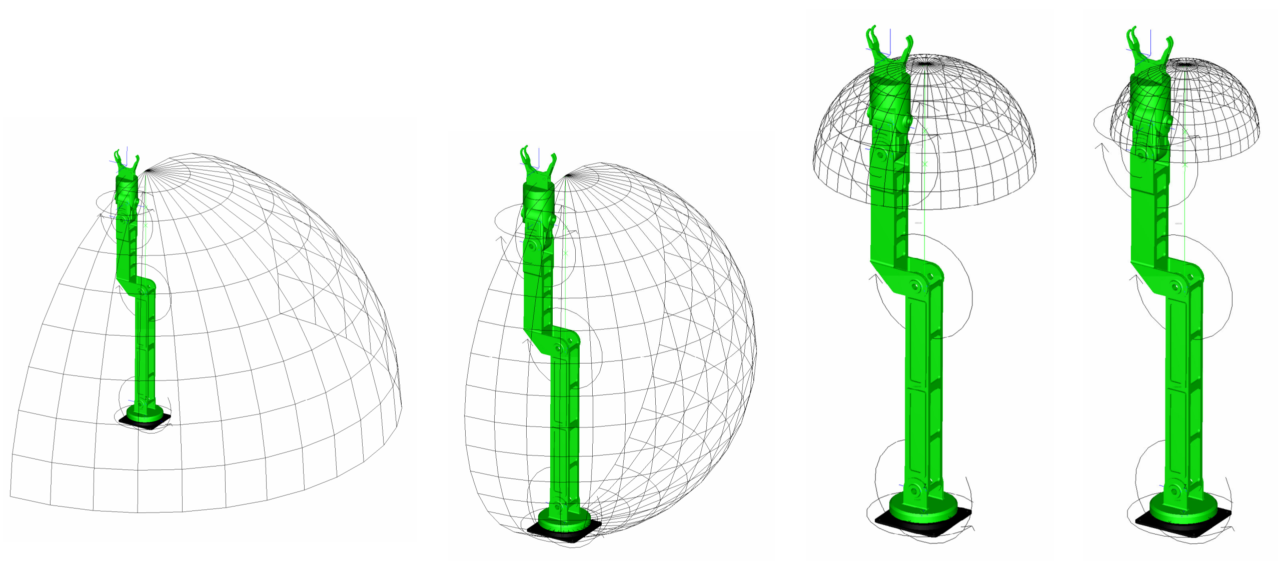
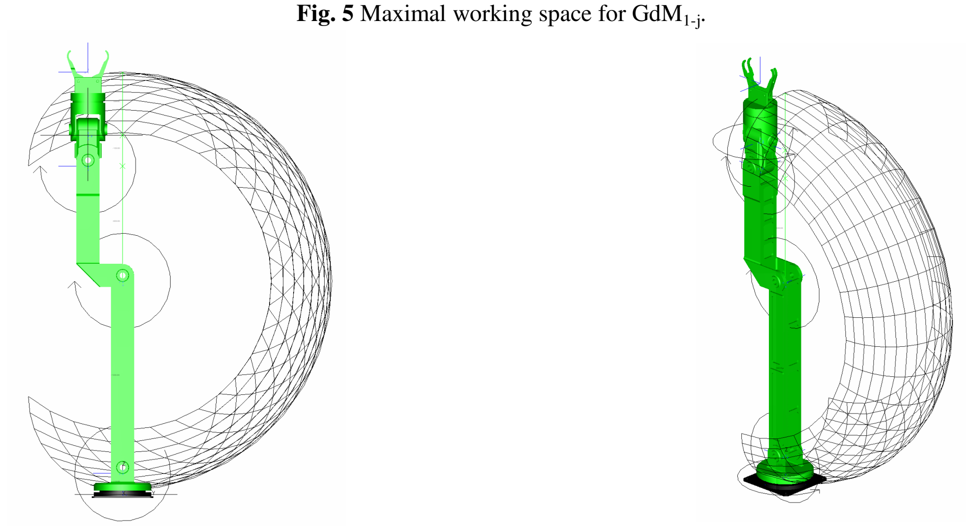


**Fig. 4** Maximal working space for the fist three GdM. of the manipulator with 6R



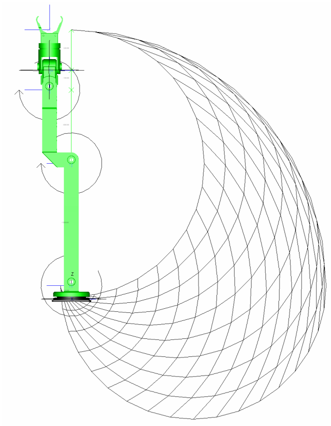
$GdM_{1-2}$ $GdM_{1-3}$ $GdM_{1-4}$ $GdM_{1-5}$

**Fig. 5** Maximal working space for $GdM_{1-j}$.

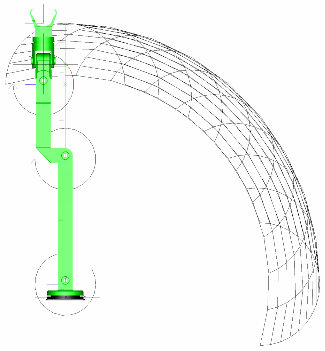


$GdM_{3-4}$ $GdM_{3-5}$

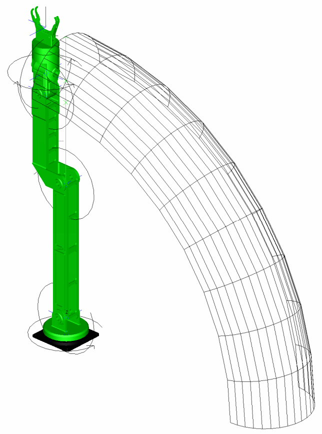
**Fig. 6** Maximal working space for $GdM_{3-j}$.



$GdM_{2-3}$



$GdM_{2-4}$



$GdM_{2-5}$

**Fig.7** Maximal working space for $GdM_{2-j}$.

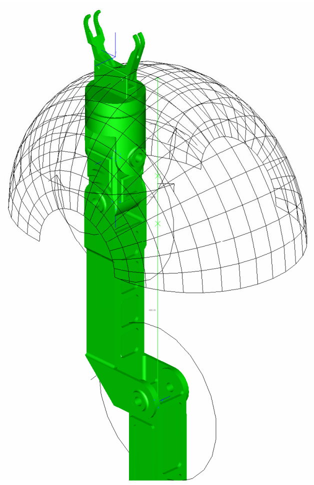


**Fig. 8** Maximal working space for $GdM_{4-5}$.

## 5. CONCLUSIONS

In this paper, a particular application of designing and creating of the limited working area for a manipulator arm is presented.

After spatial path analysis of the arm, we can make the following main remarks:

- for the first independent coordinate, corresponding to the base platform motion, was adopted $180^0$ variation domain ($-90^0$ ... $90^0$). In this way, was evaluated the extreme surface for operation with manipulator;
- the six DOF, according to the axial rotation of the prehensor, not offers supplementary information from the maximal surfaces for operation with manipulator;
- the maximal volume needed in the first three GdM using corresponds with the obtaining results through modeling and numeric simulation on the integral virtual model;
- maximal spherical surfaces, semi-toroidal or planes obtain from variations imposed on the two DOF from all six DOF of the manipulator, are characterized through spline areas determinate by the variation of the independent coordinate. The volume and area cover duty work operation with manipulator correspond the simulated situations which was analyzed with integral virtual model;
- the realized studies presented in this work with *WorkSpace* software have only cinematic character.

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