STRUCTUERE, KINEMATICS, CONSTRUCTIVE DESIGN AND COMMAND FOR A MOBILE TELETHESIS

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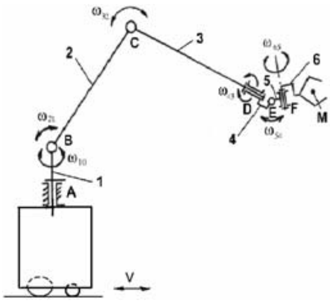
ABSTRACT
In this paper, for the first, some general aspects regarding teletheses are presented. There are distinguished the main types of teletheses: fixed or mobile teletheses. A reference telethesis is described and the main cinematic determinations for forward and inverse kinematics are done. As a typical example, STAR 2, the mobile telethesis is described. For this telethesis, it was made one constructive design and a CAD model. The telethesis is equipped with an anthropomorphic gripping system, with five fingers like the human hand. To optimize it functionally and constructively it was achieved a functional simulation of the CAD model..One command scheme is shown too.
Keywords: Mobile telethesis, Constructive design, Functional simulation

1. INTRODUCTION
A telethesis is mechatronic equipment used to help persons with handicap, around them or at distance [2,3,4]. There are fixed teletheses, which can be mounted around the persons with handicap (on the table, on the bedside table or on the wheelchair). There are as well mobile teletheses, which can perform different activities at distance (in the same room with the person with handicap, in another room or at longer distance, for example: in the garden etc.).
Teletheses have a complex mechanical structure and, in general, their main part is a robotic arm, similar to the human arm. In the paper, a mobile reference telethesis is presented with its structural peculiarities, calculation for forward and inverse kinematic, a constructive project, a CAD model and a functional simulation in CAD space and a command scheme is shown too.

2. STRUCTURE FOR A REFERENCE TELETHESIS
A telethesis must be, theoretically, similar to the human arm regarding the dimensions and the degree of freedom. A similar structure to the human arm, without the palm and the fingers, must have three movements of rotation (I, II, III), similar to the movements of the shoulder joint, one movement of rotation (IV), similar to the movement of the elbow joint and three movements of rotation (V, VI, VII), similar to the joint of the palm [5,6].
The third part of a mobile telethesis is the mobile platform, which usually has two degrees of mobility (forward – backward movement and right – left movement). As a result the total mobility of a mobile telethesis will be Mtot = 7 (for the arm) + 1 or 5 (for the gripper) + 2 (for the platform) = 10 or 14. This structure is very complex and it is difficult to achieve. Consequently a more simplified structure with M = 9 (M = 6 for the arm and M = 1 for the gripper and M=2 for the mobile platform) is preferred, see fig.1(the mobility of the gripper is not shown).

3. THE KINEMATIC FOR THE REFERENCE TELETHESIS
The area accessed by the robotic arm is essential to the utility of the telethesis. (the possibility of movement in the area closer or farther from the working point is provided by the mobile platform, as in the case of any mobile robot, which does not involve specific issues in the case of a telethesis).

Therefore, the solution of its forward and inverse kinematic problem is summarized here. These, for the reference telethesis, can be solved through different methods, well known in the theory of the mechanisms [1,2].
With the *forward kinematics*, it can be obtained the position of the characteristic point M (in the reference system $O_o x_o y_o z_o$). The local reference systems attached to the structure of the telethesis are placed in every joint, see fig. 2.



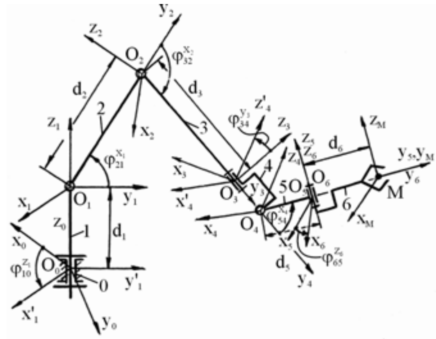


Figure 1. Simplified structure of the telethesis *Figure 2. Kinematic scheme of the telethesis*

In this figure, the distances and the angles between the reference local systems are represented too. The position of the characteristic point M is obtained with the method of the homogeneous operators [1]. Regarding this method, for a transfer from the reference system "m" to the reference system "n", the matrix of the translation operator(T_{mn}) and of the rotation operators (R_{mn}) are:

$$A_{mn} = T^x_{mn} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ d_{nm} & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}; \quad A_{mn} = R^x_{mn} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & C_{nm} & -S_{nm} \\ 0 & 0 & S_{nm} & C_{nm} \end{bmatrix}; \tag{1}$$

$$A_{mn} = R^y_{mn} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C_{nm} & 0 & S_{nm} \\ 0 & 0 & 1 & 0 \\ 0 & -S_{nm} & 0 & C_{nm} \end{bmatrix}; \quad A_{mn} = R^z_{mn} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & C_{nm} & -S_{nm} & 0 \\ 0 & S_{nm} & C_{nm} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

In these matrice $S_{nm} = \sin\varphi_{nm}$, and $C_{nm} = \cos\varphi_{nm}$. The position of the characteristic point M in the reference system $O_o x_o y_o z_o$ is: $A_{0M} = A_{01}\, A_{12}\, A_{23}\, A_{34}\, A_{45}\, A_{56}\, A_{6M}$, where:

$A_{01} = R^z_{01} \cdot T^z_{01}$; $A_{12} = R^x_{12} \cdot T^y_{12}$; $A_{23} = R^x_{23} \cdot T^y_{23}$; $A_{34} = R^y_{34} \cdot T^y_{34}$; $A_{45} = R^x_{45} \cdot T^y_{45}$; $A_{56} = R^z_{56}$; $A_{6M} = T^y_{6M}$.

With the *inverse kinematics*, the rotation of the pivot joints for a position of the characteristic point M can be obtained. If we know the elements of the A_{0M} matrix:

$$A_{0M} = T^x_{mn} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ b_{21} & b_{22} & b_{23} & b_{24} \\ b_{31} & b_{32} & b_{33} & b_{34} \\ b_{41} & b_{42} & b_{43} & b_{44} \end{bmatrix}; \tag{2}$$

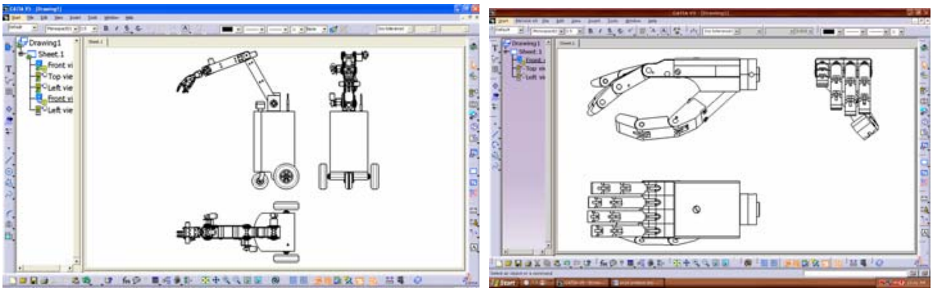
for inverse kinematics, the following equation is used:

$$A_{01}\, A_{12}\, A_{23}\, A_{34}\, A_{45}\, A_{56}\, A_{6M} = A_{0M} \tag{3}$$

With inverse operators, $A_{01}^{-1}, A_{12}^{-1}, A_{23}^{-1},...,$ a system is obtained and then its solutions, depending on the matrices: A_{01}, A_{12}, A_{23}… A45, A_{56}, A_{6M}

4. CONSTRUCTIVE DESIGN, CAD MODEL AND FUNCTIONAL SIMULATION

Based on the structural-cinematic layout, the technical design of the telethesis was done, see fig.3,a. It has a robotic arm with the main dimensions of the "arm and forearm" similar to the human upper member, it is equipped with an anthropomorphic gripper with five mono mobile fingers, see fig.3,b, at this stage, with the possibility of transforming it into a pentamobile gripper at a subsequent version and a mobile platform [7].



a b

Figure 3. Constructive design of the mobile telethesis

In addition, the telethesis is equipped with cameras and a system for receiving the command signal by radio waves and, obviously, with appropriate command equipment. Based on the technical project the CAD model was created in the CATIA software, see fig.4.
To optimize constructively and for the identification of certain constructive and technical differences, the functional simulation in CATIA was done, without an object to be gripped and with an object grasped, see fig. 5. Through this simulation there can be highlighted the work area of the telethesis, and by default the limit positions, and there can be identified locations of other auxiliary components so that they are accessible and the objects to be manipulated can be gripped and brought to the utility area of the beneficiary.

Figure 4. CAD model of the telethesis

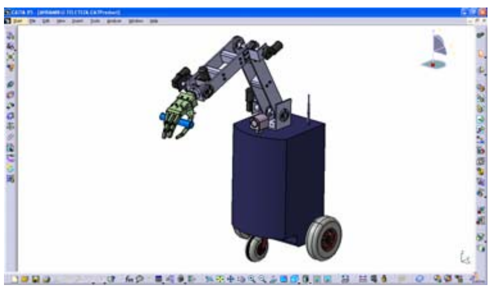


Figure 5. CAD simulation

Furthermore, the CAD model was transferred to the virtual environment, which is the VRML software for virtual simulation. Simulation in virtual environment in addition to estimating the functional performance of the telethesis allows as well the operator's training concerning the use of the telethesis (obviously there is required the development of appropriate sub programmes). In the virtual model in the first instance, only the prehension module has been connected with a CYBER GLOVE for the command. By the command with a CYBER GLOVE, one can simulate the operation of the anthropomorphic gripping system to obtain different configurations of fingers and the simulation of prehension of objects with different shapes to identify the optimal gripping positions.
In this phase, it was obtained by feed - back the sight of the contact between the virtual gripping

system and the object, which is gripped, and its transfer from one position to another.
The simulation of the telethesis performance in the virtual reality (VRML) had in view carrying out some operations of prehension and transfer of some pieces, in the first instance, of relatively simple forms (e.g. a cylindrical piece).

5. COMMAND SCHEME

The general scheme for command and control subsystem is shown in fig. 6. Tha main devices of this scheme are: a *control center* with the components: laptop, joystick, frame graber board, data processing block, power supply, receiver with frequency changing block, E/R station , transmision reception block(for cable connection) and a *robot-telethesis received equipment* with the components: images transmission block(for video cameras), E/R station, data processing block, IMD sources with serial command, motors block, motor - generator and energy source + special battery.

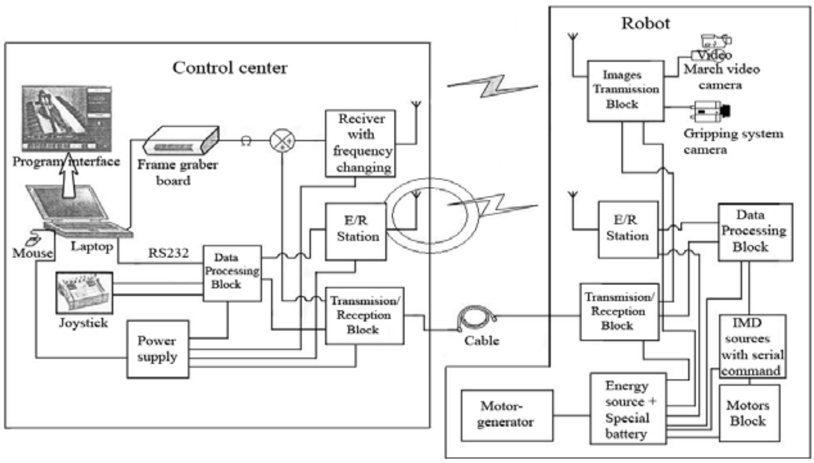


Figure 6. Command scheme

6. CONCLUSIONS

The following conclusions, regarding the aspects presented in this paper, can be formulated:
- teletheses are mechatronic structure and robotic too, and it is complex equipment fixed or mobile, which can be used to substitute one or both human arms;
- the main part of the mobile telethesis is a robotic arm, which can be cinematically analyzed (forward and inverse kinematics) similar to kinematic analysis of the industrial robots;
- a constructive design, CAD model, and functional simulation in CAD space and virtual space are useful stages to obtain better versions of the teletheses;
- these mechatronic structures must be commanded with adequate command schemes.

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