Research on the field of the Intelligent Robot System Control for the Construction

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Abstract

This paper is engaged in the development of the intelligent robot control system of the robot ALR-4.1 for the construction. At this is necessary to solve great number of tasks, for example the robot - technologies, design, control system, trajectory planning, servodrive control, collision free motion planning etc.
This is solved at the state tasks of the Grant Agency of Czech Republic on the topics " The Computer Control and Design of the Multiaxes Robots " and "The Adaptive grippers for industrial robots ".

1. The possibilities of the robot application for the construction in Czech Republic

The construction production after the transformation of Czech state economics to the private market orientated economics is developed quickly on the field of non-residential buildings. This development is connected with the construction of banks, shops, industrial production enterprises etc. The other fields are the Czech express high way and express railway construction. For the future is also necessary quicker development of the residential buildings. [10]

2. The development on the field of robotics for the construction at TU Brno is possible to divide:

a) The development of the series of multi purpose industrial robots for the construction, machine industries etc. It was developed the series of industrial cartesian portal type robots PRKM, the series of cartesian bridge type robots PRM and it is developed the series of anthropomorphic 6-axes robots ALR-4 type.
The bridge type robots PRM-55 and PRM-200 are applicated in the construction industry [6].

b) The analysis and preparation of the suitable robot technologies for the construction.
These technologies are possible to divide on:

- **OFF-site robot technologies**, for example the welding of the materials, the manipulation with the construction materials, the preparation of the constructin prefabricates - painting of the forms etc.
- **ON-site robot technologies** - for example the walls building up, the finishing works - for example the walls plaster, painting etc.
- **The catrastrophic effect removing** - they are prepared at TU Brno the anthropomorphic angular heavy robots AHR series [1].

3. The development and the control of the anthropomorphic 6-axes robot ALR-4.1

At TU Brno we are developing 6-axes anthromorphic robot ALR-4.1 as the first member of the prepared geometric series of ALR robots. [1]
The ALR-4.1 robot has own design, the harmonic gearboxes, el. servodrives with synchronous motors and PC computer control system.
The software development for the 6-axes ALR robots:

The trajectory planning

a) the robot movement analysis, based on the transform matrix:

$$^{0}\mathbf{T}_6 = {}^{0}\mathbf{T}_1 \cdot {}^{1}\mathbf{T}_2 \cdot {}^{2}\mathbf{T}_3 \cdot {}^{3}\mathbf{T}_4 \cdot {}^{4}\mathbf{T}_5 \cdot {}^{5}\mathbf{T}_6$$

T - rotation matrix with translation

b) the robot movement synthesis, based on geometrical substitution and orthogonal matrix:

$$^{3}\mathbf{R}_6 = ({}^{0}\mathbf{R}_3)^{-1} \cdot {}^{0}\mathbf{R}_6$$

R - rotation matrix

c) the robot movement simulation (see Fig. 1) based on the objects and functions of the ALR-4.1 robot movement program:

- **frame** - the object describing of the position and orientation of the robot end-effector in the space,
- **smove**(frame&target) - the robot movement function - the linear interpolation,
- **cmove** - the robot movement function - the circle interpolation.

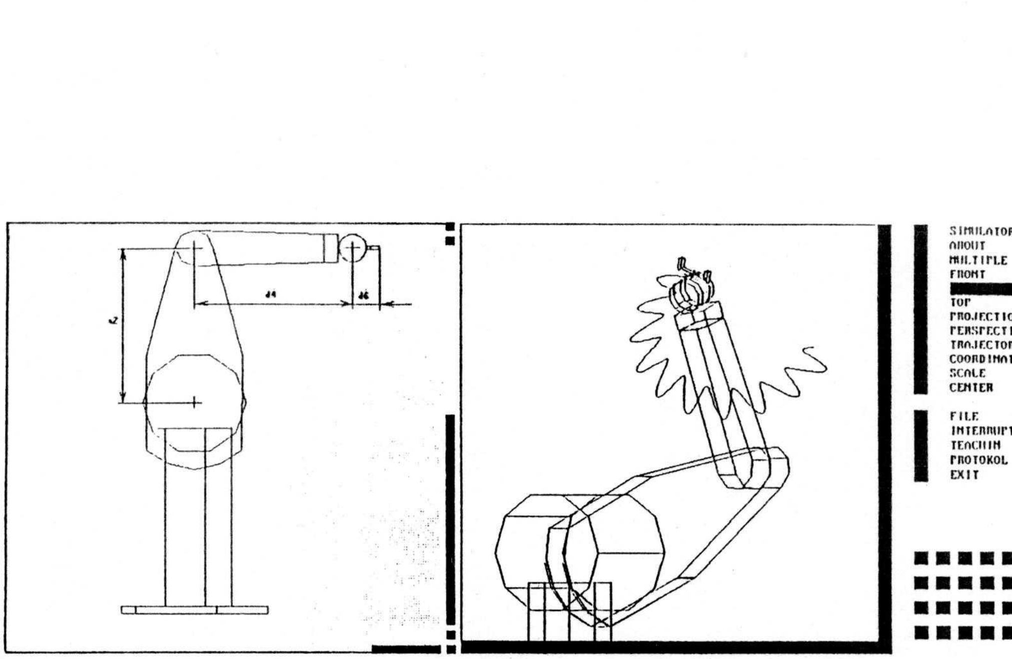
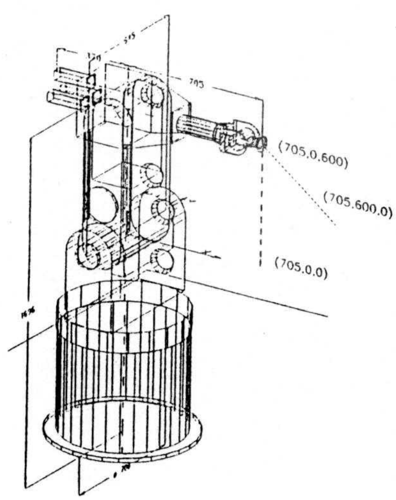


Fig. 1 The robot ALR-4.1 movement simulation

d) <u>The velocity generation for the ALR-4.1 robot servodrives control</u> - based on the program for the robot trajectory planning.
From the given robot trajectory and the ALR-4.1 robot trajectory planning program (see above) we get the robot joint turning (see Fig. 2), that multiplied by the gear ratio we get the servodrive turning and divided by the time interval specification we get the servodrive velocity turning.



	ALR - 4.1					
	φ_1 [°]	φ_2 [°]	φ_3 [°]	φ_4 [°]	φ_5 [°]	φ_6 [°]
	0.00000	0.00000	0.00000	-314.00000	0.00000	-44.00000
(705,0,600)	4.24620	0.31578	3.94126	-314.99413	6.00994	-44.84798
	8.44627	1.26147	7.26406	-314.95320	11.97898	-44.41610
	12.55700	2.82870	9.96963	-314.84285	17.85598	-43.74325
	16.54062	4.99748	12.05115	-314.63094	23.58137	-42.87291
	20.36649	7.73306	13.49842	-314.28952	29.09038	-41.85395
	24.01189	10.98536	14.30167	-313.79704	34.31685	-40.74041
	27.46196	14.69110	14.45449	-313.14005	39.19774	-39.59044
	30.70903	18.77844	13.95559	-312.31420	43.67809	-38.46451
	33.75148	23.17320	12.80910	-311.32387	47.71550	-37.42333
	36.59249	27.80548	11.02353	-310.18060	51.28315	-36.52568
	39.23880	32.61549	8.60930	-308.90061	54.37083	-35.82665
	41.69959	37.55768	5.57534	-307.50166	56.98378	-35.37681
	43.98553	42.60328	1.92483	-305.99999	59.13967	-35.22253
	45.00000	45.00000	0.00000	-305.26439	60.00000	-35.26439
(705,600,0)						

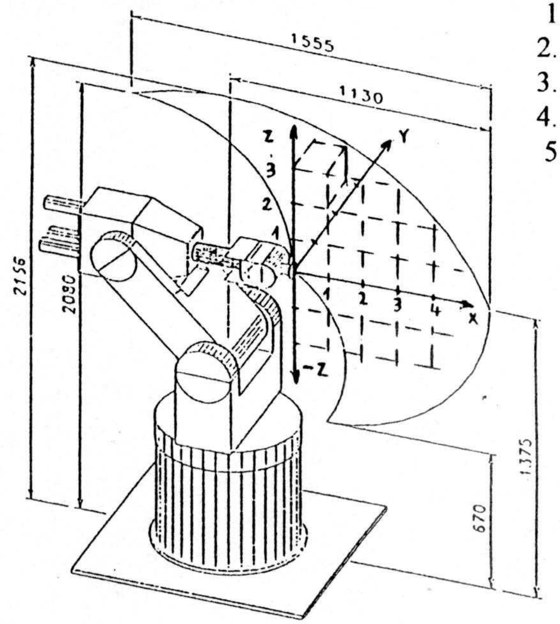
	ALR - 4.1					
	φ_1 [°]	φ_2 [°]	φ_3 [°]	φ_4 [°]	φ_5 [°]	φ_6 [°]
	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
(705,0,600)	0.00000	0.31663	5.70966	0.00000	6.02629	0.00000
	0.00000	1.27468	10.83317	0.00000	12.10785	0.00000
	0.00000	2.89386	15.38998	0.00000	18.28385	0.00000
	0.00000	5.19723	19.37807	0.00000	24.57530	0.00000
	0.00000	8.20247	22.77961	0.00000	30.98208	0.00000
	0.00000	11.91254	25.56597	0.00000	37.47851	0.00000
	0.00000	16.30630	27.70294	0.00000	44.00924	0.00000
	0.00000	21.33136	29.15671	0.00000	50.48808	0.00000
	0.00000	26.90191	29.89999	0.00000	56.80189	0.00000
	0.00000	30.00000	30.00000	0.00000	60.00000	0.00000
(705,0,0)						

Fig. 2 Robot ALR-4.1 and its trajectory generation for the servodrives control

4. The development of the robot ALR-4.1 collision free motion planning for the construction

a) The classification and the dividing of the robot work space

The robot work space is possible to divide on the sub - spaces, for example after the distance of the obstacle (see Fig. 3) :



1... VS - very small,
2... LS - little small,
3... MD - medium,
4... LB - little big,
5... VB - very big.

Fig. 3 The robot ALR-4.1 work space dividing

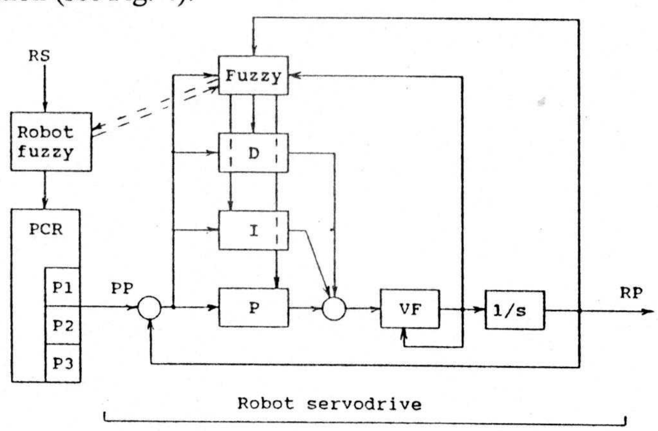
The distance is necessary evaluate in the three axes x, y, z.
This problem is three dimensional (the combination of three distances in two geom. levels).
The distance specification is connected with robot work space and velocity in the axes x, z, z.
For the future is necessary to use the dynamic dividing of the robot work space by using of the dynamic optimalization (the logistic method of the operation research). Bigger velocity means smaller time for the trajectory change.

b) ON- LINE robot control

Now we are preparing to use ultrasonic sensors for this robot and the computer robot control based on the programs for the robot trajectory planning optimalization and the robot servodrive control optimalization.
For the future we will be prepare multi-processor control system - each processor will be control one task (for example the communication, the trajectory planning, the servodrive optimalization, the evaluation of the information from the sensors etc.).

c) The time and space robot movement analysis for the robot decision, how to continue in its movement in the next time movement steps.
It is prepared the using of the dynamic optimalization robot trajectory movement (the method of the LOGISTIC operation research)
We suppose to test this robot at first for the rectangular obstacle avoiding (for example at the robot painting of the walls etc.).
It will be necesary to decision, how to continue on its trajectory, if it is the line , the right corner, the left corner etc. (the control strategy).

d) The obstacle avoiding
Here we are using the solution from the research mentioned above and we are preparing to use the FUZZY LOGIC for:
1) Quicker decision for the trajectory change:
- D : the distance of the obstacle (VS, LS, MD, LB, VB),
- S : the size of the obstacle (VS, LS, MD, LB, VB),
- V : the velocity function of the servodrive (VS, LS, MD, LB, VB),
- RC: the right corner,
- LC: the left corner,
- RCR: the right corner robot trajectory movement program (new trajectory),
- LCR: the left corner robot trajectory movement program (new trajectory generation).
--> the trajectory (the velocity) change:
example: **IF** D = VS and S = VB **THEN** V = VS; **IF** RC **THEN** RCR;
IF LC **THEN** LCR;
2) The using of the FUZZY LOGIC for the servodrive control optimalization :
based on the position , the velocity, we get the optimalization of the servodrives acceleration (see Fig. 4).



PP .. Program position, P .. P regulator,
RP .. Real position, I ..I regulator,
VF .. Velocity feedback, D .. D regulator,
PCR ..PC robot control system, RS ...Robot scene,
Fuzzy .... Fuzzy logic of the servodrive,
P1, P2, P3 ... robot trajectory planning programs,
Robot fuzzy... Fuzzy logic of the robot scene.

Fig. 4 FUZZY LOGIC at the servodrive mechatronic control

5. The relations between the robot system computer control and the management factory control

The using of the knowledge from the Logistics (optimalization: linear, dynamic etc.), SPC (statistical process control), FUZZY LOGIC, Computer nets, CIM, Intelligent systems, Heuristics etc.) for quicker decission, new models of the robot control - the factory management control etc. [[2], [3], [8] etc.]

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