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MODELING OF THE CELL STRUCTURES OF ROBOTIZED SYSTEMS

MODELOVANIE BUNKOVÝCH ŠTRUKTÚR ROBOTIZOVANÝCH SYSTÉMOV

Abstract

For increasing the efficiency of technical progress is necessary to automate the engineer's work. Although there is a wild area of using the systems of automated constructing, technological background of production and projecting (CAD, CAP, CAx), in specialized areas is necessary an additional progress. Important stage of software products development is modeling a solved problem. Common additions in the field of creating geometrical models of objects are showed into the additions in the field of modeling of the structures of production systems.

Advantages:

- Exploitation in the projection of structures of production systems
- Applicability for automated systems, for systems with man attendance, or to combinations of them, too
- Increase of the accuracy of the modeling against to the most of yet used methods
- Accordance of methodical progress:
    - in creating model databases (objects of produce, elements of production systems, structures of production systems)
    - in the using of parametrical model databases (objects of produce, elements of production systems, structures of production systems)

For the modeling of the cell structures of production systems with robots were designed a new principle of solving topological relations. This paper describes the suggested model of solution.

Abstrakt

Pre zvýšenie efektívnosti technického rozvoja je nutná automatizácia inžinierskej práce. I keď je to široká oblasť systémov, automatizácia sa stáva technologickým podkladom produkcie a projektovania (CAD, CAP, CAx), v špecializovaných oblastiach je potrebný ďalší vývoj. Dôležitým stupňom programového vývoja produktov je modelovanie a riešenie problému. Všeobecnými princípmi pri tvorbe geometrických modelov objektov sú vložené do príloh na poli modelu štruktúr výrobných systémov.

Výhody:

- Využitie pri navrhovaní štruktúr výrobných systémov
- Vhodnosť pre automatizované systémy, systémy s ľudskou obsluhou, alebo kombinované systémy
- Zvýšenie presnosti modelovania oproti doteraz najviac používaným metódam
- Zhoda so systematickým vývojom:

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- tvorba modelu databázy (predmetov výroby, elementov výrobného systému, štruktúr výrobných systémov)
- využitie parametrického modelu databázy (predmetov výroby, elementov výrobného systému, štruktúr výrobných systémov)

Pre modelovanie bunkových štruktúr výrobných systémov s robotmi, kde je navrhnutý nový princíp riešenia topologického spojenia. Tento príspevok popisuje návrh modelu riešenia.

For modelling of cell structure of production systems with robot was suggested a principle of solution of topological relation showed on Fig. 1.

1. The first step is a selection of handling element (i.e. type of robot or human operation – man, woman – different several anthropometric data). The loading point of handling element becomes a starting point of the cell coordinate system. $IP_M \equiv O_{x,y,z}$

2. From database the first building element is selected. The loading point is set in X-axis of cell coordinate system into R_1 distance from the origin of the cell coordinate system, i.e.:

$IP_1 = [\, R_1,\ 0,\ \ 0 \,]$

Radius R_1 (see Fig. 2) is chosen from the interval: $R_1 \in \langle\, R_{1min}\,,\ R_{1max} \,\rangle$ so there is maximum superposition of working zones for a handling device and the cell relevant elements. Superposition index is: $k_p = t_p \,/\, (t_{iR} + t_{par}) \ \rightarrow$ max

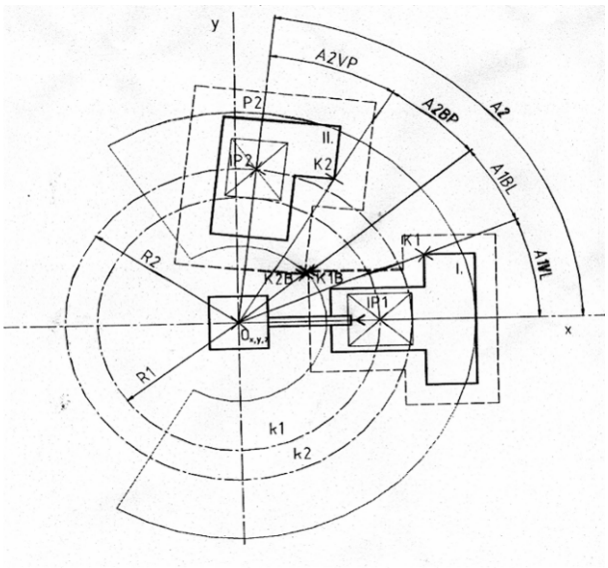

Fig. 1 Model of topological relations in pilot structure of production systems

Interval bounds R_{1min} and $R_{1\,max}$ are determined as the intersection points of line P_{HP} , which is interlaid over the working point of element $WP_1 = [\ x_{wp1},\ y_{wp1},\ \ H_{wp1}\ ]$ parallel with X-axis and the limit curves of the working zone for handling devices $\{k_1,\ k_2\,, \ldots,\ \ k_n\ \}$, where n determines number of limit curves.

$P_{HWP1} \cap \{\ k_1,\ k_2\,, \ldots,\ \ k_n\ \}\ =\ \{\ P_1,\ P_2\ \}$

$P_1\ =\ [\ R_{1min}\,,\ 0\ ,\ H_{WP1}\ ]\ ,\ P_2 =\ [\ R_{1max}\,,\ 0\ ,\ H_{WP1}\ ]$

There are following cases:

a) $P_{HWP1} \cap \{\ k_1,\ k_2\,, \ldots,\ \ k_n\ \}\ =\ \{\ P_1,\ P_2\ \} \qquad \Rightarrow\ \ R_1 \in \langle\, R_{1min}\,,\ R_{1max} \,\rangle$

b) $P_{HWP1} \cap \{ k_1, k_2, \ldots, k_n \} = \{ P_1 \} \Rightarrow R_{1min} == R_{1max} = R_1$

c) $P_{HWP1} \cap \{ k_1, k_2, \ldots, k_n \} = \{\emptyset\} \Rightarrow \{ \emptyset \} \Rightarrow$ non - isadvisable R_1,
i.e. there is necessary change for height of working point $HWP1$.

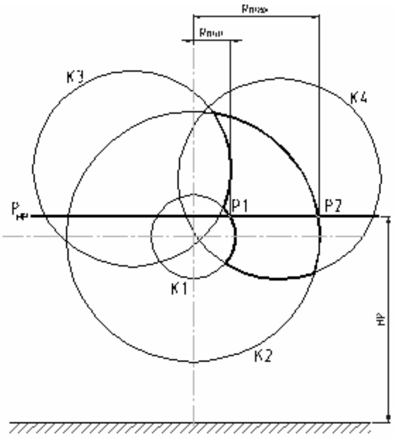

Fig. 2 Radius determination R

3. Selection for the next building element from database.

4. Interactive determination of semi-space (L or P). In this semi-space there is set building element model (for the next possibility we can predict that element is set into L semi-space).

5. Automated calculation of element position.

a) An angle with element 1 is calculated:

$\alpha_{1vl} = \text{arctg } B_{1L} / (R_1 - L_{1L})$,

where B_{1L}, L_{1L} - are coordinates of critical element point 1 in L semi-space (concerning determined radius R_1).

b) safety angle between elements 1 and 2 (α_{B1-2}) is determined as sum of angles:

$\alpha_{1BL} = \text{arctg } B_{1BL} / (R_1 - L_{1BL})$, $\alpha_{2BP} = \text{arctg } B_{2BP} / (R_2 - L_{2BP})$,

where : $B_{1BL}, L_{1BL}, B_{2BP}, L_{2BP}$ coordinates of critical points for elements 1 and 2 of safety zones in semi-space L and P: $\alpha_{B1\text{-}2} = \alpha_{1BL} + \alpha_{2BP}$

An angle with element 2 is calculated:

$\alpha_{2VP} = \text{arctg } B_{2P} / (R_2 - L_{2P})$,

where: B_{2P}, L_{2P} - are coordinates of critical element point 2 in P semi-space (concerning determined radius R_2).

d) Loading point for element 2 (IP_2) is on a line P_2 crossing the origin of the cell coordinate system $O_{x,y,z}$ and with X-axis forming an angle:

$\alpha_2 = \alpha_{1VL} + \alpha_{B1\text{-}2} + \alpha_{2VP}$

As well the loading point for element 2 is on a circular line K_2 with centre in point $O_{x,y,z}$ and with radius R_2. Loading point position IP_2 is determined as position of intersection $P_2 \cap K_2$. A line P_2 is determined with equation in outline expression. : $y = k\,x + q$,

where : k – gradient of line: $k = \text{tg } \alpha_2$

q - intercept which is determined with the line on Y-axis: q=0 and then

It is valid that: $P_2 : y = x. \text{ tg } \alpha_2$

A circular line $K_2 = [O_{x,y,z}, R_2]$ is determined with equation:

$x^2 + y^2 = R^2$, because $O_{x,y,z} = [0 , 0 , 0]$

The point coordinates $IP_2 = [x_{IP2} , y_{IP2}]$ re obtained with solution of system of equations:

$$y_{IP2} = x_{IP2} . \text{ tg } \alpha_2 \quad (1)$$

$$x^2_{IP2} + y^2_{IP2} = R^2_2 \quad (2)$$

It is valid that :

$x_{IP2} = R_2 / \sqrt{1 + \mathrm{tg}^2\alpha_2}$

$y_{IP2} = R_2 \,.\, \mathrm{tg}^2\alpha_2 / \sqrt{1 + \mathrm{tg}^2\alpha_2}$

Element 2 is inserted in point $IP_2 = [\, x_{IP2} , y_{IP2} , 0 \,]$ turned off at an angle α_2 .

6. The determination of rest angle α_{ZL} (α_{ZR}) for relevant semi-space:

$\alpha_{ZL} = \alpha / 2 - \alpha_2 - \alpha_{ZVL},$

where: α - angle of working space for handling device.

7. Insertion of the next element?

For calculation of position for i element:

a) There is a radius determined $R_i \in \langle R_{imin} , R_{imax} \rangle$.

b) Safety angle between element i and *i*-1 $\alpha_{(i-1)-iB}$ are sum of safety angles :

$\alpha_{B(i-1)}$, α_{Bi} .

$\alpha_{B(i-1)} = arc\mathrm{tg}\, B_{(i-1)B} / (R_{(i-1)} - L_{(i-1)B})$

$\alpha_{Bi} = arc\mathrm{tg}\, B_{iB} / (R_i - L_{iB})$

$\alpha_{(i-1) \rightarrow B} = \alpha_{(i-1)B} + \alpha_{iB}$

c) Angle with i elements $\alpha_{iV} = arc\mathrm{tg}\, B_i / (R_i - L_i)$.

d) Element is set in point IP_i determined with polar coordinate system : $IP_i = [\, R_i , \alpha_i \,]$, where element radius vector IP_i and positive direction of *X*-axis make an angle

$\alpha_i = \alpha_{(i-1)V} + \alpha_{(i-1)-iB} + \alpha_{iV}$

The Cartesian coordinates for a position of inserting point IP_i is:

$x_{IPi} = R_i / \sqrt{1 + \mathrm{tg}^2\alpha_i}$

$y_{IPi} = R_i \,.\, \mathrm{tg}^2\alpha_i / \sqrt{1 + \mathrm{tg}^2\alpha_i}$

e) Rest angle (i.e. dropped angle of working space for handling device) is determined with equation:

$\alpha_Z = \alpha / 2 - (\alpha_i - \alpha_{iV}),$

If *i*-element is positioned in the left semi-space then: $i = i_L$

$\alpha_{(i-1)B} = \alpha_{(i-1)BL}$	$B_{(i-1)B} = B_{(i-1)BL}$
$\alpha_{iB} = \alpha_{iBP}$	$B_{iB} = B_{iBP}$
$\alpha_{(i-1)V} = \alpha_{(i-1)VL}$	$L_{(i-1)B} = L_{(i-1)BL}$
$\alpha_{iV} = \alpha_{iVP}$	$L_{iB} = L_{iBP}$
$\alpha_{iV} = \alpha_{iVL}$	$B_i = B_{2P}$
$\alpha_Z = \alpha_{ZL}$	$L_i = L_{iP}$

If *i*-element is positioned in the right semi-space then: $i = i_P$

$\alpha_{(i-1)B} = \alpha_{(i-1)BP}$	$B_{(i-1)B} = B_{(i-1)BP}$
$\alpha_{iB} = \alpha_{iBL}$	$B_{iB} = B_{iBL}$
$\alpha_{(i-1)V} = \alpha_{(i-1)VP}$	$L_{(i-1)B} = L_{(i-1)BP}$
$\alpha_{iV} = \alpha_{iVP}$	$L_{iB} = L_{iBL}$
$\alpha_{iV} = \alpha_{iVP}$	$B_i = B_{iL}$
$\alpha_Z = \alpha_{ZP}$	$L_i = L_{iL}$

It is possible that at the application of relevant method on elements, which are characterised with a difficult shape of zone with maximum dimensions or safety zone, there is left a reserve angle between elements $i - 1$ and i. This angle should decrease the angle, which is between relevant elements. Correction of position for an element is performed with a reduction of angle with value of angle correction.

There is the possibility of angle correction in critical element points (for critical ones are considerate points where zone shape is changed into the maximum element dimensions or the shape of safety element zone).

Calculation of correction has got two steps (Fig.3, Fig. 4).

Correction $i \rightarrow (i - 1)$

It is valid that:

$\alpha_{j,(i-1) \rightarrow i} = \alpha_{j,(i-1)} - \alpha_{j,i}$

$\alpha_{j,i}$ = arcsin $y_{j,i}$ / $\sqrt{x^2_{j,,i} + y^2_{j,i}}$
$\alpha_{j,i}$ = arcsin $y_{j,(i-1)}$ / $\sqrt{x^2_{j,i(i-1)} + y^2_{j,i(i-1)}}$

Conseqvential angle correction:
$\alpha_{i \to i(i-1)} = \min \{ \alpha_{j,i \to (i-1)} \}$, $j = 1, 2, ..., m$

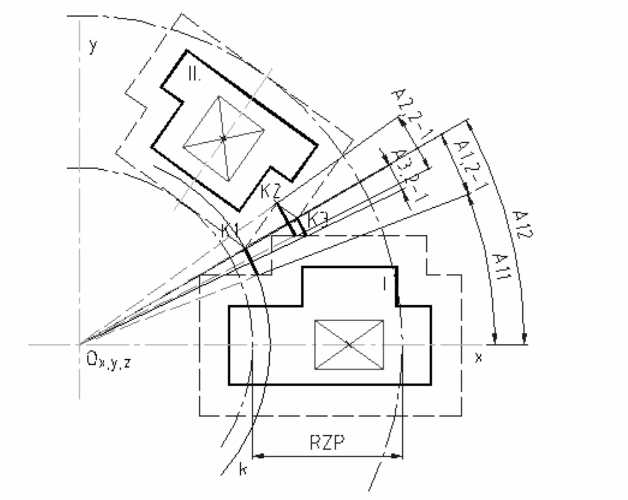

Fig. 3 Calculation of correction $\alpha_{i \to (i-1)}$

Correction $(i-1) \to i$
It is valid that:
$\alpha_{j,(i-1)\to i} = \alpha_{j,(i-1)} - \alpha_{j,i}$
$\alpha_{j,i}$ = arcsin $y_{j,i}$ / $\sqrt{x^2_{j,i} + y^2_{j,i}}$
$\alpha_{j,i}$ = arcsin $y_{j,(i-1)}$ / $\sqrt{x^2_{j,i(i-1)} + y^2_{j,i(i-1)}}$

Conseqvential angle correction:
$\alpha_{(i-1)\to i} = \min \{ \alpha_{j.i \to (i-1)} \}$, $j = 1, 2, ..., m$

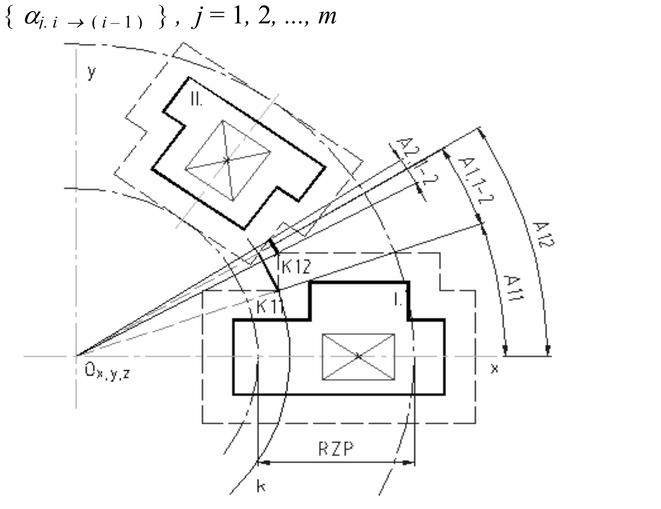

Fig. 4 Calculation of correction $\alpha_{(i-1)\to i}$

Sumary angle correction:
$\alpha_R = \min \{ \alpha_{j \to (i-1)}, \alpha_{j \to (i-1)} \}$

Parametric structure models production systems are universal and flexible from the point of application possibilities (cutting, assembly, etc.) and degree of automation (non automated, automated manufacturing systems) and at the same time provide higher level for optimization by the spacing problem solution.

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