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MACHINE SHOP PORTAL MANIPULATOR MOVEMENT PATH MODELING FOR DIGITAL MANUFACTURING

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Machining workshops are often equipped with specialized units to allow heavy loads transportation. Often, the workshop is equipped with a large portal manipulator (PM), which is used for auxiliary operations like moving objects from/to holding locations, as well as between work areas. Operating time cost of such manipulators is relatively high, which is caused by a number of factors: operating with one object at a time leads to a queue, low movement speed and long distances increase path efficiency requirements, the estimated masses objects require powerful engines usage. There is an additional opportunity for increasing efficiency of such important mechanism as PM in digital production context due to decreasing workshop area population. This can be achieved, among other things, by reducing auxiliary time via forming an optimized manipulator's end effector (EE) movement path.

In robotics, there are many approaches to planning manipulator path. There are methods on the base of graphs, methods of potential fields, using cell decomposition, intellectual and others. Many various methods are based on similar mathematics. Moreover, a very important aspect of path search method applicability is chosen method of robot's operating area and obstacles representing convenience. Such methods as object-dependent, regular or adaptive decomposition, visibility graphs methods, exploring tree methods [1], hierarchical search, quasi-random and pseudo-random points choice, and others are applied. While some path methods can achieve greater path optimization, others provide more complete solution, and still others differ in speed due to the reduced accompanying calculations complexity [1]. Hybrid methods with best advantages and less flaws compared to separate methods are commonly used.

The approach proposed for PM movement path modeling involves a multi-level processing. It includes manipulator's invalid configurations set calculation and periodic updating, considering load dimensions, as well as PM operating area's neural map creation and activation using wave-front propagation method [2], route network creation for making EE PM path's reference points sequence. It is also proposed to use hierarchical methods for increasing path's detailing and smoothing, depending on reference path's initial detailing.

Manipulator's invalid configurations set is based on updatable obstacle data for more detailed workshop layout mapping, manipulator's movement time and auxiliary operations time reduction. Various operating area's parts availability will change during work process, like in the holding area, for example. Proposed method allows take-away cost pre-evaluation for holding areas' items considering their next destination point. Logistic algorithms may use such data to raise items accessibility and make placements that are more beneficial.

For operating area representation, the cell decomposition approach with a given discreteness is applied. Each piece of 3D space accommodates a set of PM's configurations and is associated with one artificial neuron.

The Hopfield neuron model is used. Neuron i is described by input vector Y, weight vector W_i, displacement vector θ_i, that form a sum network signal

$$u_i = W_i \times Y + \theta_i = \sum_{j=1}^{n} w_{ij} v_j + \theta_i .$$

The sum signal is processed by a nonlinear activation function Φ and formed the output signal of the neuron Y_i. Hyperbolic tangent, sigmoidal function and others can be used as activation function. Piecewise given function is chosen as a weight function of the i-th and j-th neurons

$$w_{ij} = \begin{cases} 0 & \rho\left(q_i, q_j\right) = 0; \\ f\left(\rho\left(q_i, q_j\right)\right) & 0 < \rho\left(q_i, q_j\right) < r; \\ 0 & r < \rho\left(q_i, q_j\right), \end{cases},$$

where ρ(qi, qj) – Euclidean distance between configurations, corresponding to i and j neurons; f(ρ(qi, qj)) – decreasing function of the form f(x) = 1/x; r – neutron region radius i.e. how far each neuron affects other neurons' weights [3].

Few artificial neuron digital representation options with different synoptic connections types and number were tested during test simulations, using the QT cross-platform framework. Several neural map activation methods, like 2d/3d rasters and wave propagation application, as well as static and dynamic obstacles processing methods were also considered. Activated route map and three-dimensional path are visualized through QT v4.5 built-in libraries and third-party point clouds visualizing applications, for example, Aviz Cubix [4]. Such visualization is not required during the PM operation, but is extremely useful for clarifying the results, development and debugging of digital model.

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