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Adaptive Visual Mobile Robot Control

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Abstract. *The work is devoted to modern Industry 4.0 approaches, such as mobile robot visual control on manufacturing plant. The main idea is a solution of the actual problem a flexible integrated robotic system control using an adaptive visual control system. The research methods are based on the usage of the research results analysis of modern theoretical and applied developments of native and foreign scientists in the field of adaptive visual control models and methods. Information and software support for the control system for a mobile transport robot has been developed, practically realizes the analysis of the working space using a computer / technical vision system and provides the selection of the main objects of the workspace, the identification of work and individual objects of space, obtaining their spatial coordinates, which improves the quality and speed of functioning flexible integrated robotic system.*

Keywords: *adaptive visual control, mobile robot, flexible system, manufacturing, models, methods.*

I. Introduction and Problem Statement

The development of flexible integrated systems, robotic tools and intelligent control systems demonstrates the increasing role and importance of sensor systems in decision-making on solving technological problems at specific workplaces for manipulation robots, on the paths of transport robots and a combination of manipulation and transport tasks.

The basis for obtaining information about the environment from a person is its visual system. As a rule, damage or absence of the visual system prevents a person from performing both ordinary everyday tasks and complex work operations. On the other hand, the presence of sight in a person does not mean the acquisition of the ability to accurately measure the parameters of objects in the surrounding space without special equipment, it is rather difficult to accurately estimate the distance to objects or determine their orientation and size [1].

The problem of modeling the human visual system in intelligent control systems is quite successfully solved by creating systems of technical and computer vision. However, the problem lies in determining the degree of integration of artificial visual functions of technical systems with the executive mechanisms of automated equipment, handling and transport robots. In other words, technical and computer vision systems should be integrated into intelligent control systems in such a way as to provide support for automated control processes in real time, with simultaneous monitoring of the progress of processes and, if necessary, correction of control actions.

One of the approaches to solving problems caused by uncertain or changing system parameters is the use of adaptive control methods. Adaptation is a process of purposeful change in the parameters and structure of the system, which consists in determining the criteria for its functioning and the fulfillment of these criteria [2].

Adaptive visual control is the control based on the adaptation of the system to changes in the parameters of the working environment of the robotic system, based on information coming from the technical vision system (visual subsystem) in the process of the system functioning [3].

The main feature of adaptive visual control systems is the ability to obtain visual information in the process of functioning and use this information to implement control functions.

An example of an adaptive visual control system application can be a mobile robot equipped with an onboard technical or computer vision system (or a technical / computer vision system can be global – located above the workspace). During the execution of a movement task, dynamic obstacles may appear on the path of the robot's movement – other jobs, people, vehicles, equipment moved. The technical / computer vision system should immediately send a command to work about the obstacles presence, at the moment, of their appearance, and the intelligent control system should decide how to continue the task assigned to the robot by sending control actions to it, adapt the control system to changes in the workspace [4].

II. Problem Solution and Results

The creation of any model of control objects is impossible without a model of the workspace, in which they are present such objects, perform the actions assigned to them.

Let us consider the construction of a model of the workspace of a flexible integrated system (FIS), in which the tasks of controlling mobile robots are posed [5-6].

Let there be a workspace (WS) W_s of robot Rb. Space is described by such properties:

– geometric dimensions $D(x,y,z)$;

– a set of objects in space Obj;

– a period of time T_{param} existence of WS;

Then the space can be written as follows:

$$W_s = <D(x,y,z), Obj, T_{param}>$$

Each of the objects of the objects set Obj of workspace has a unique identifier ID, which means the ability to identify an object, including using a barcode, QR codes, and the like.

It is necessary to take into account the main property of space – its discreteness and finiteness (limitedness). In the end, we will understand the limits of the working space of the camera. The case of open (unlimited) space is, in principle, a separate task.

By discreteness we mean the division of space into cells equal in length and width. Depending on the level of discretization of the WS, it is possible to set the task of moving (or manipulating) control objects of different accuracy. The discrete nature of the working space means the presence of the coordinates of the objects located in the RP and the K_{FL} – binary occupancy factor of the WS section:

$$D(z,y,z)=\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{l}d(x_i,y_j,z_k),\ K_{FL}\in[0,1]$$

where $d(x_i,y_j,z_k)$ – geometrical parameters of a discrete space cell, K_{FL} – cell fill factor. It should also be borne in mind that all cell parameters must be the same size.

$$K_{FL}=\frac{S_{FL}(d(x,y,z))}{S(d(x,y,z))},K_{FL}\le 0.25$$

where $S(d(x,y,z))$ – discrete space cell area, $S_{FL}(d(x,y,z))$ – filled part of a discrete space cell $d(x,y,z)$.

The FIS workspace assumes the existence of certain objects Obj – verstats (Vr), instrument (Ins), equipment (Osn), humans (Hum), robots (Rb), storages ($Storage$), conveyors ($Conv$), workspace monitoring devices (Mon) :

$$\exists Vr\in W_s;\ \exists Ins\in W_s;\ \exists Osn\in W_s;\ \exists Hum\in W_s;$$
$$\exists Rb\in W_s;\ \exists Storage\in W_s;\ \exists Conv\in W_s;\exists Mon\in W_s.$$
$$Obj=\langle Vr,Ins,Osn,Hum,Rb,Storage,Conv,Mon\rangle$$

From this it follows that from the point of view of declaring properties, the entire FIS can be expressed by the expression:

$$FIS=\langle W_s,Rb,Vr,Ins,Osn,Hum,Storage,Conv,Mon\rangle$$

Each of the objects has properties set. These properties have specific values that are included in the set of property names and values.

There are belonging relations between objects and their properties, that is, certain properties belong to a certain object (the object has certain properties).

Objects of workspace W_s exist both statically and dynamically.

Static objects that do not change their position and do not affect the states of movement of the robot, include such machine objects (Vr), conveyors ($Conv$) and storages ($Storage$).

Dynamic objects that can change their position and thus change to affect the state of movement of the robot in the workspace are as follows: tool (Ins), equipment (Osn), humans (Hum).

Monitoring the dynamics of the workspace is provided by monitoring devices, which include global computer / technical vision systems (GTVS) – $Camera_{Glob}$ and local systems of computer / technical vision (LTVS) – $Camera_{Loc}$, other sensors of a condition of working space ($Sens$).

All properties of objects can be written in the form of tuples of parameters [6].

$$\forall v\in Vr,\exists v=\langle Type_{Vr},D_{Vr}(x_{Vr},y_{Vr},z_{Vr}),PM_{Vr},Sc_{Vr},ID_{Vr}\rangle$$

$$\forall ins\in Ins,\exists ins=\langle Type_{Ins},D_{Ins}(x_{Ins},y_{Ins},z_{Ins}),PM_{Vr},ID_{Ins}\rangle$$

$$\forall o\in Osn,\exists o=\langle Type_{Osn},D_{Osn}(x_{Osn},y_{Osn},z_{Osn}),ID_{Osn}\rangle$$

$$\forall h\in Hum,\exists h=\langle D_{Vr}(x_{Vr},y_{Vr},z_{Vr}),Mv_{Hum}(x_{HumMv},y_{HumMv},z_{HumMv}),Per_{Hum},Exp_{Hum},Age_{Hum},Qual_{Hum},ID_{Hum}\rangle$$

$$\forall rb\in Rb,\exists rb=\langle D_{Rb}(x_{Rb},y_{Rb},z_{Rb}),Mv_{Rb}(x_{Rb},y_{Rb},z_{Rb}),Speed_{Rb},Cp_{Rb}(x_{cpRb},y_{cpRb},z_{cpRb}),ID_{Rb}\rangle$$

$$\forall storage\in Storage,\exists storage=\langle D_{Storage}(x_{Storage},y_{Storage},z_{Storage}),Type_{Storage},Quan_{Storage},ID_{Storage}\rangle$$

$$\forall conv\in Conv,\exists conv=\langle D_{Conv}(x_{Conv},y_{Conv},z_{Conv}),Type_{Conv},Quan_{Conv},Speed_{Conv},ID_{Conv}\rangle$$

$$\forall mon\in Mon,\exists mon=\langle Camera_{Glob},Camera_{Loc},Sens\rangle$$

At the same time, the monitoring system consists of surveillance cameras and sensors of different types and purposes.

In particular, the camera has the following properties:

$$\forall cam\in Cam,\exists cam=\langle Inst_{pt}(x_{pt},y_{pt},z_{pt}),Angle_{View},Resolution\rangle$$

III. CONCLUSIONS

The research methods are based on the use of the analysis of domestic and foreign scientists modern theoretical and applied developments research results in the field of models and methods of adaptive visual control.

As a result of theoretical and practical research, a declarative model of the workspace has been developed, which reflects FIS objects characteristic of the intelligent work control and communication between objects tasks, and which, unlike the existing ones, takes into account the discreteness and fullness of the production workspace; based on information received from global computer vision systems; defines and takes into account the properties of objects placed in the workspace; takes into account the interaction, ordering and compatibility of objects.

REFERENCES

[1] Artem Bronnikov, Nevliudov Igor, Oleksandr Tsymbal. Flexible manufacturing tendencies and improvements with visual sensoring / Eskisehir Technical University Journal of Science and Technology. Applied Sciences and Engineering, 2019. Vol. 20, ICONAT issue, P. 77-83.

[2] Бронніков А.І. Сучасний стан та перспективи розвитку гнучких інтегрованих систем / Технология приборостроения. Харьков, 2018, № 1 , С. 54 - 57.

[3] Tsymbal O., Bronnikov A. Decision-making information technology for flexible integrated manufacturing / Сучасний стан наукових досліджень та технологій в промисловості. 2019. № 2 (8). – С. 105-112.

[4] Nevliudov I., Tsymbal O., Bronnikov A., Mordyk O. Internet of things for robotic projects / Сучасний стан наукових досліджень та технологій в промисловості. 2020. № 3 (13). – С. 58-64.

[5] Цимбал О.М., Замірець М.В., Мордик О.О., Бронніков А.І., Корнілова Ю.Б. Інтелектуальні методи відеоспостереження: аналіз методів реалізації / Технология приборостроения. Харків, 2020, № 1, С. 35 - 40.

[6] Бронніков А.І., Адаптивное визуальное управление производственным агентом / Технология приборостроения. Харьков, 2016, № 3 , С. 3 - 6.