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INFORMATION MODELS FOR MANUFACTURING WORKSPACES IN ROBOTIC PROJECTS

The **subject** of research in the article are the workspace models for flexible integrated robotic systems. The **goal** of the work is in development of information models to represent workspaces for following application in the automated control systems of flexible integrated manufacturing. The article solves the next **tasks:** to analyze the representation of workspace to decide practical problems of robotic systems of different nature, to consider the development of informational models for representation on workspaces of intelligent control systems of integrated manufacturing, to consider the practical examples of information presentation on workspaces of production systems. Research **methods** are set theory and predicate theory. The following **results** were obtained: there were analysed the main features of informational models development to solve robotic tasks of different nature and were pointed the limitations of existing approaches of formal description, the need of integration of workspace models to decision-support systems and systems of graphical and mathematical simulation of integrated systems; the set theory-based model of information representation for problem-solving processes of flexible integrated robotic systems is proposed; the information-logic model of workspace for mobile robot applications, functioning in flexible integrated systems. is developed and contains the list of objects, includes their geometrical dimensions and supplies the preservation of parameters in time and space; information presentation for automated control system of flexible integrated manufacturing, which implements proposed models, is considered. **Conclusions:** application of models of information type for automated control systems makes to supply logical unification of flexible integrated manufacturing elements, to provide monitoring of states of technological equipment of production systems in space and time and formation of their digital twins, to promote functioning of intelligent decision-support systems for robotic systems of different types, that improves characteristics of production control.

Keywords: information model; workspace; mobile robot; flexible integrated system.

Introduction

While Industry 4.0 as a concept of economy and society development quit recently celebrated its 10th anniversary in 2021 [1], the implementation of this concept still doesn't cover a lot of different fields. Successful examples of Industry 4.0 applications first of all connected to creation of new manufacturing units, which incorporate novel production ideas just from first step. Another case is for elderly production areas with their existing structure, logistics, equipment, and services. They can become great attention points for Industry 4.0 applications to get new impacts to production processes and to achieve new sufficient levels without huger investments, compared to creations of new manufacturing units.

Simultaneously, application of new industrial concepts defines huge rise of information on every production element and its numerous connections to other elements. At the level of model, each parameter of the system must be taken in account. In these conditions, development of informational models becomes important but routine procedures for manufacturing systems simulation and development. Such simulation of manufacturing objects makes essentially real the idea of digital twins for any element of flexible systems.

Current article considers approaches to build informational models of workspaces for flexible integrated robotic systems, for the following support of intelligent decision-making systems of robots, also to support concept of digital twins of manufacturing units.

1. Analyses of existing approaches for robotic workspace presentation

Simulation and presentation of robotics workspaces started many years before appearance of current manufacturing concepts, for example, in STRIPS problem solver [2] the workspace (WS) of an intelligent robot was described as a set of predicate-described facts, connecting static and dynamic properties of WS areas, position of robot and object of production process. Other approach, described in [3] deals with same ideas as STRIPS but for Human Robotic Collaborative workspace, divided into passive resources (working tables, fixtures etc.) and active resources (humans and robots) given a task and secondly, with the number and type of active resources to be selected for a task. Thus, authors of [3] propose to organize WS in form of facts and actions with estimation of floor spaces, reachability of robotic resources, ergonomics, and investments (see fig. 1), while with minor formal description of WS properties.

In [4] authors consider human-robot collaboration for adaptive autonomous systems, including robot assistants. They consider human-robot team as a Markov decision process (MDP), with states of robotic world (WS) $x \in X$, robotic actions $a^R \in A^R$, and human actions $a^H \in A^H$. The proposed decision-making system evolves according to a probabilistic state transition function $p\left(x' \mid x, a^R, a^H\right)$, that specifies the probability of transitioning from state x to state x`, when actions a^R and a^H are applied in state x. Also, [4] proposes to store the history of interactions between robot and human in time.

Research in [5] suggest to look at manipulation of robotic systems as a knowledge-based system, supported by skills and presents a method for automatically generating planning problems from existing skill definitions such that the resulting problems can be solved using off-the-shelf planning software, and the solutions can be used to control robot actions in the world. The key role for robotic WS representation here is provided by

SkiROS and its world model. According to [6] The world state is partially predefined by a human operator in the ontology, partially abstracted from the robot by perception, and completed with the procedural knowledge embedded in the skills and primitives, that is shown in figure 2.

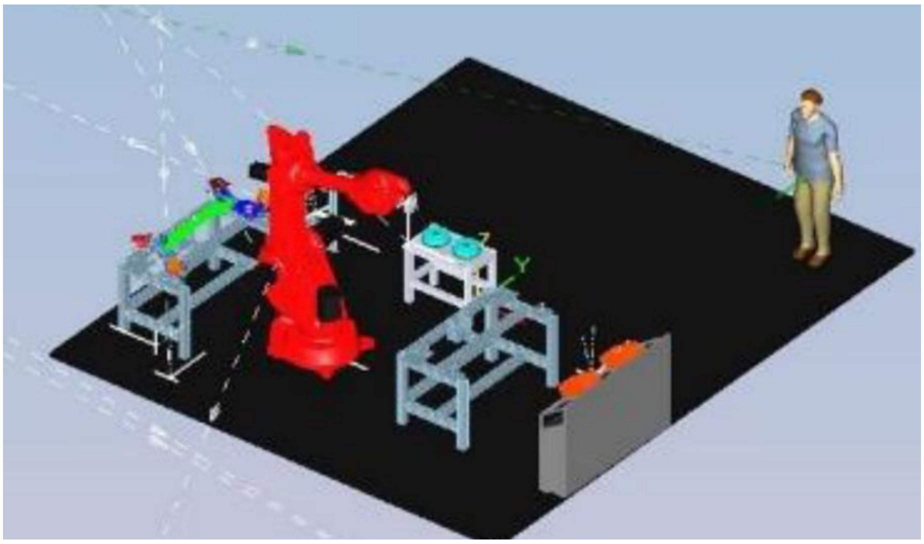

Fig. 1. Optimized workspace layout for manufacturing robotic cell [3]

Article [7] considers knowledge presentation of robotics systems from different levels: abstraction of low-level features (features that can be acquired by a robotic system) with high-level knowledge that can be interpreted by humans, described as skills. Transfer of skills (manipulations) is provided by demonstration of human actions and next imitation of them by the robot manipulator. Problems of robotic system workspaces presentation are also discussed in [8 - 10].

For instance, [8 - 9] proposes the formal description of data for robot's automated control system (ACS). ACS from strategies planning viewpoint is depicted by sets:

Robotic technical system (RTS as part of FIS), with states of set $x_i \in X, i = 0 \ldots n-1$, is a vector of states $X = \left\{X^0, X^1, \ldots, X^{n-1}\right\}$, that at time moments $t_0, \ldots, t_{n-1}$ has values $X_0 = \left\{x_0^0, x_0^1, \ldots, x_0^{n-1}\right\}$, $X_1 = \left\{x_1^0, x_1^1, \ldots, x_1^{n-1}\right\}, \ldots,$ $X_{n-1} = \left\{x_{n-1}^0, x_{n-1}^1, \ldots, x_{n-1}^{n-1}\right\}$.

RTS exists in a workspace (WS) $s_i \in S, i = 0 \ldots m-1$.

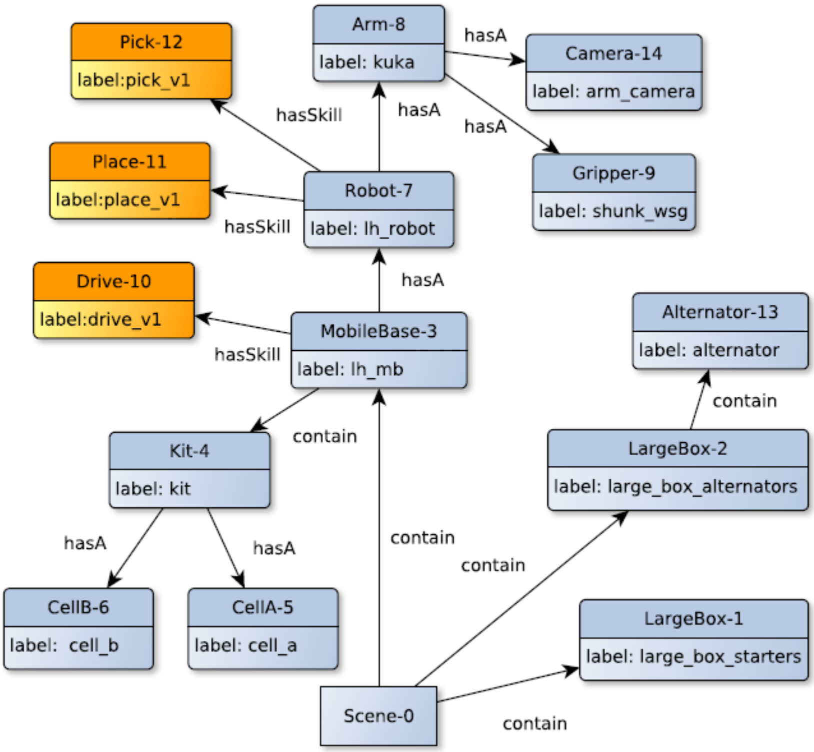

Fig. 2. World model instance for physical (blue) and abstract (orange) objects in [5]

WS is 2-dimensional or 3-dimensional and depends of time. The set of specifications of WS is given as vector of states $S=\left\{S^{0},S^{1},\ldots,S^{n-1}\right\}$ and at the time moments $t_0,\ldots,t_{n-1}$ has the values $S_0=\left\{s_0^0,s_0^1,\ldots,s_0^{n-1}\right\}$, $S_1=\left\{s_1^0,s_1^1,\ldots,s_1^{n-1}\right\}$,…, $S_{n-1}=\left\{s_{n-1}^0,s_{n-1}^1,\ldots,s_{n-1}^{n-1}\right\}$;

RTS can generate decisions $d_k\in D, k=0...l-1$ on transformation of its states and states of WS. The set of decisions, generated by strategies planning system (SPS) defines vector $\vec{D}=\left\{d_0,d_1,\ldots,d_{m-1}\right\}$, with m – the number of decisions for times $t_0,\ldots,t_{n-1}$;

Decisions are implemented by RTS actions: $a_i\in A, i=0...l-1$.

The set of actions $A=\left\{a^0,a^1,\ldots,a^{n-1}\right\}$ is executed by RTS as implementation of found decisions $\vec{D}_i$ with subsets of movements or manipulations $a_{mv}\subset A$, $a_{mp}\subset A$.

The purpose of RTS functioning is a state $y\in X$, which is reached by sequential states transitions: $x_0\to x_1\to ...\to x_{n-1}=y$.

Therefore at process of target achievement there are transformations:

$$x_1=f_1(x_0,y,s_0,d_0,a_0)+\varepsilon_0,\quad \|x_1-x_0\|\le\varepsilon_0,$$

……………………………………..

$$x_k=f_k(x_{k-1},y,s_{k-1},d_{k-1},a_{k-1})+\varepsilon_k,\quad \|x_k-x_{k-1}\|\le\varepsilon_k,$$

……………………………………..

$$y=f_n(x_{n-1},y,s_{n-1},d_{n-1},a_{n-1})+\varepsilon_n,\quad \|y-x_{n-1}\|\le\varepsilon_n,$$

f – transition function, ε – transition error.

Transitions are described by cost $c_i\in A, i=1...n$ and duration $t_i\in T, i=1...n$. The aim is to find such sequence of transitions $f_1,\ldots,f_n$, which will supply the system transition from initial state x_0 to purpose y.

Conditions of search are: $\sum_{i=1}^{n}t_i\to\min$, $\sum_{i=1}^{n}c_i\to\min$, $\sum_{i=1}^{n}\varepsilon_i\to\min$.

The mentioned sets present the real elements of ACS and provide information support for decision-making system of mobile or manipulation robots, acting as a part of flexible integrated production system.

2. Information-logical model of mobile robot workspace

The creation of any control objects model is impossible without a workspace model in which there are such objects that perform their tasks [11 - 13].

Let us consider the construction of a workspace model of a flexible integrated manufacturing system (FIMS), in which the tasks of mobile robot control are set.

Let there be a workspace W_s of robot Rb. Workspace is described by properties:

- geometric dimensions $D(x,y,z)$;
- a set of space-belonging objects Obj;
- time interval T_{param} of WS existence.

Then the space can be written as follows:

$$W_s=<D(x,y,z),Obj,T_{param}> \tag{1}$$

Each of the objects of the WS objects set Obj has a unique identifier ID, which means the ability to identify the object, using barcodes, QR codes, etc.

It is necessary to consider the main property of space – its discreteness and finiteness (limitedness). By finiteness we mean the limits of the camera working space. The case of opened (unlimited) space is, in principle, a separate problem.

By discreteness, we mean the division of space into cells that are the same in length and width. Depending on the WS discretization level, it is possible to set the tasks of moving (or manipulating) control objects of different accuracy.

The discrete nature of the working space means the presence of the coordinates of objects located in the WS and the occupancy factor of the WS section:

$$D(z,y,z)=\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{l}d(x_i,y_j,z_k),\ K_{FL}\in[0,1], \tag{2}$$

where $d(x_i,y_j,z_k)$ – geometric parameters of a discrete space cell, K_{FL} – cell fill coefficient. All cell parameters must be the same size.

$$K_{FL}=\frac{S_{FL}(d(x,y,z))}{S(d(x,y,z))},K_{FL}\le 0.25, \tag{3}$$

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

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

$$\begin{gathered}\exists Vr\in W_s;\exists Ins\in W_s;\exists Osn\in W_s;\exists Hum\in W_s;\exists Rb\in W_s;\\ \exists Storage\in W_s;\exists Conv\in W_s;\exists Mon\in W_s\end{gathered} \tag{4}$$

$$Obj=<Vr,Ins,Osn,Hum,Rb,Storage,Conv,Mon>. \tag{5}$$

It follows from this that, from the point of view of property declaration, the entire GIVS can be expressed by the expression:

$$FIS=<W_s,Rb,Vr,Ins,Osn,Hum,Storage,Conv,Mon>. \tag{6}$$

Each of the objects owns a set of parameters. These properties have specific values, are included in a set of property names and values. Table 1 shows the main characteristics of objects in the symbolic representation.

There are ownership relations between objects (objects) and their properties, that is, certain properties belong to a certain object. An example of the properties of objects is also presented in table 1.

An example of the scheme of the workspace and the objects in it is shown in fig. 3, which shows the need to consider the human factor when planning transportation operations for mobile robots.

Workspace objects W_s exist both statically and dynamically.

The following objects can be carried to the static objects, which do not change the position and do not influence states of the robot movement: verstats (Vr), conveyors ($Conv$) and storages ($Storage$).

Dynamic objects that can change their position and thereby affect the movement state in the workspace are: instruments (Ins), equipment (Osn), humans (Hum).

Observation of the dynamics of the working space is provided by monitoring devices, which include object systems of computer / technical vision (OVSC) – $Camera_{Glob}$ and local computer / technical vision systems (LVSC) – $Camera_{Loc}$, other workspace status sensors ($Sens$).

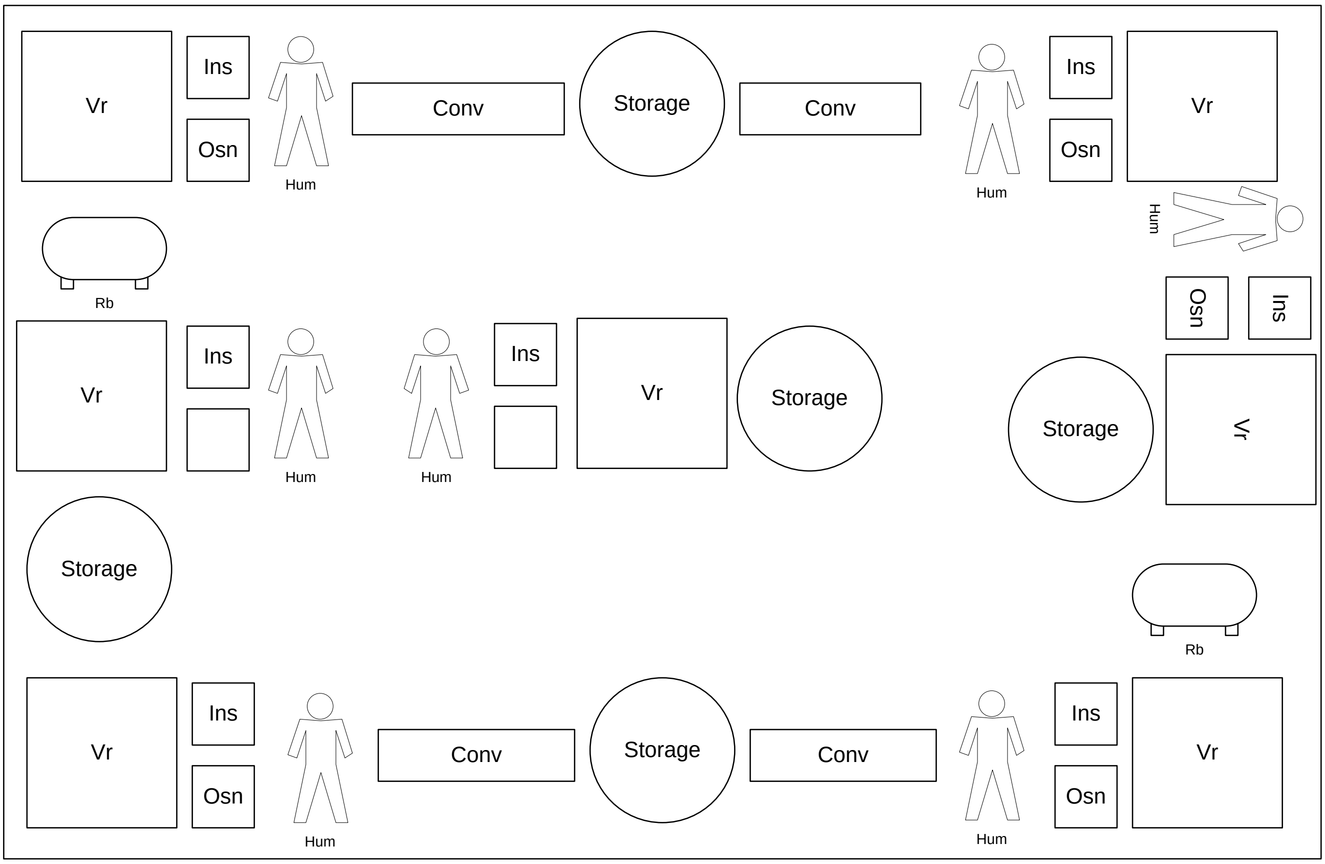

Fig. 3. An example of the objects locations in the workspace

Table 1. *List of objects* Obj *properties*

Object	**Object property** $Param_{Obj}$	**Property name indication**
Vr	Verstat type	$Type_{Vr}$
	Geometric parameters	$D_{Vr}(x_{Vr}, y_{Vr}, z_{Vr})$
	Processing methods	PM_{Vr}
	Special conditions	Sc_{Vr}
	Unique identifier	ID_{Vr}
Ins	Instrument type	$Type_{Ins}$
	Geometric parameters	$D_{Ins}(x_{Ins}, y_{Ins}, z_{Ins})$
	Processing methods	PM_{Ins}
	Unique identifier	ID_{Ins}

The end **Table 1.**

Osn	Equipment type	$Type_{Osn}$
	Geometric parameters	$D_{Osn}(x_{Osn}, y_{Osn}, z_{Osn})$
	Unique identifier	ID_{Osn}
Mon	OVSC	$Camera_{Glob}$
	LVSC	$Camera_{Loc}$
	Other sensors	$Sens$
Hum	Geometric parameters	$D_{Hum}(x_{Hum}, y_{Hum}, z_{Hum})$
	Movement parameters in workspace	$Mv_{Hum}(x_{HumMv}, y_{HumMv}, z_{HumMv})$
	Belonging to the staff	Per_{Hum}
	Experience	Exp_{Hum}
	Age	Age_{Hum}
	Quality	$Qual_{Hum}$
	Unique identifier	ID_{Hum}
Rb	Geometric parameters	$D_{Rb}(x_{Rb}, y_{Rb}, z_{Rb})$
	Movement parameters in workspace	$Mv_{Rb}(x_{Rb}, y_{Rb}, z_{Rb})$
	Movement speed	$Speed_{Rb}$
	Current position	$Cp_{Rb}(x_{cpRb}, y_{cpRb}, z_{cpRb})$
	Unique identifier	ID_{Rb}
Object	Object property $Param_{Obj}$	Property name indication
Storage	Geometric parameters	$D_{Storage}(x_{Storage}, y_{Storage}, z_{Storage})$
	Type	$Type_{Storage}$
	Quantity of parts	$Quan_{Storage}$
	Unique identifier	$ID_{Storage}$
Conv	Geometric parameters	$D_{Conv}(x_{Conv}, y_{Conv}, z_{Conv})$
	Type	$Type_{Conv}$
	Quantity of parts	$Quan_{Conv}$
	Speed	$Speed_{Conv}$
	Unique identifier	ID_{Conv}

According to table 1, all properties of objects can be written in the form of tuples of parameters.

$$\forall v \in Vr, \exists v =< Type_{Vr}, D_{Vr}(x_{Vr}, y_{Vr}, z_{Vr}), PM_{Vr}, Sc_{Vr}, ID_{Vr} > \quad (7)$$

$$\forall ins \in Ins, \exists ins =< Type_{Ins}, D_{Ins}(x_{Ins}, y_{Ins}, z_{Ins}), PM_{Vr}, ID_{Ins} > \quad (8)$$

$$\forall o \in Osn, \exists o =< Type_{Osn}, D_{Osn}(x_{Osn}, y_{Osn}, z_{Osn}), ID_{Osn} > \quad (9)$$

$$\begin{gathered}\forall h \in Hum, \exists h =< D_{Vr}(x_{Vr}, y_{Vr}, z_{Vr}), Mv_{Hum}(x_{HumMv}, y_{HumMv}, z_{HumMv}), \\ Per_{Hum}, Exp_{Hum}, Age_{Hum}, Qual_{Hum}, ID_{Hum} >\end{gathered} \quad (10)$$

$$\begin{gathered}\forall rb \in Rb, \exists rb =< D_{Rb}(x_{Rb}, y_{Rb}, z_{Rb}), Mv_{Rb}(x_{Rb}, y_{Rb}, z_{Rb}), Speed_{Rb}, \\ Cp_{Rb}(x_{cpRb}, y_{cpRb}, z_{cpRb}), ID_{Rb} >\end{gathered} \quad (11)$$

$$\begin{gathered}\forall storage \in Storage, \exists storage =< D_{Storage}(x_{Storage}, y_{Storage}, z_{Storage}), Type_{Storage}, \\ Quan_{Storage}, ID_{Storage} >\end{gathered} \quad (12)$$

$$\begin{gathered}\forall conv \in Conv, \exists conv =< D_{Conv}(x_{Conv}, y_{Conv}, z_{Conv}), Type_{Conv}, Quan_{Conv}, \\ Speed_{Conv}, ID_{Conv} >\end{gathered} \quad (13)$$

$$\forall mon \in Mon, \exists mon =< Camera_{Glob}, Camera_{Loc}, Sens > . \tag{14}$$

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

Cameras have the following properties:

$$\forall cam \in Cam, \exists cam =< Inst_{pt}(x_{pt}, y_{pt}, z_{pt}), Angle_{View}, Resolution > \ . \tag{15}$$

All objects of the working space interact with each other by various kinds of dependencies, which allows us to introduce a definition.

Definition 1. Each workspace object has at least one property.

$$\forall x(x \in Obj)\exists param(param \in Param_{Obj})[x(param)], \tag{16}$$

where $\forall$ – general quantifier, $\exists$ – quantifier of existence, x – a WS specific object, Obj – set of WS objects, $Param_{Obj}$ – set of object parameters.

$Param_{Obj}$ set of objects properties includes parameters such as: $Param_{Vr}$ – set of verstats properties, $Param_{Ins}$ – set of intstruments properties, $Param_{Osn}$ – set of equipment properties, $Param_{Hum}$ – set of human poperties, $Param_{Rb}$ – set of robot properties, $Param_{Storage}$ – set of storage properties, $Param_{Conv}$ – set of conveyor properties, as described in table 1.

Hence:

$$\begin{gathered} Param_{Obj} = Param_{Vr} \cup Param_{Ins} \cup Param_{Osn} \cup \\ \cup Param_{Hum} \cup Param_{Rb} \cup Param_{Storage} \cup Param_{Conv} \end{gathered} . \tag{17}$$

From these definitions it follows that:

$$\forall x \exists Param_{Obj}[Param_{Vr}(x)], \tag{18}$$

$$\forall x \exists Param_{Obj}[Param_{Ins}(x)], \tag{19}$$

$$\forall x \exists Param_{Obj}[Param_{Osn}(x)], \tag{20}$$

$$\forall x \exists Param_{Obj}[Param_{Hum}(x)], \tag{21}$$

$$\forall x \exists Param_{Obj}[Param_{Rb}(x)], \tag{22}$$

$$\forall x \exists Param_{Obj}[Param_{Storage}(x)], \tag{23}$$

$$\forall x \exists Param_{Obj}[Param_{Conv}(x)]. \tag{24}$$

Definition 2. Each object of space relates to any object with another object:

$$\forall x \exists y (x \leftrightarrow y). \tag{25}$$

The definition is correct since each of the objects is designed to interact with other objects.

Definition 3. All FIMS workspace are ordered in relation to others:

$$\forall x \exists y, \{x,y\}. \tag{26}$$

Definition 4. For each item in the workspace, there is another item that is compatible with the first one in the process of work:

$$\forall x \exists y, x \cap y. \tag{27}$$

The definition is true since each of the robotic area objects exists in order to participate in the technological process.

Definition 5. There are such items that predetermine each other in the technological process.

$$\forall x \exists y, x \to y\ . \tag{28}$$

This relation is a special case of expression by definition 4, so it exists between the same objects.

Definition 6. There are the same objects.

$$\forall x \exists y \in x \equiv y\ . \tag{29}$$

Definition 7. For each property value $param_i$ there will be a match for him. Symbolically, this expression can be written as:

$$\forall param_i \exists param_j([param_i] = [param_j]). \tag{30}$$

Definition 8. For each numerical value of a property (except for the maximum value on a finite set of values), you can find a value greater than the current one.

$$\forall param_i \exists param_j([param_i] < [param_j], param_i \in N, param_j \in N) \tag{31}$$

In addition to the FIMS workspace, where the robot works, there is another one – the warehouse equipment space $Warehouse$, which interacts with the FIMS and has a set of characteristics, in particular geometric parameters $D_{Warehouse}(x_{Warehouse}, y_{Warehouse}, z_{Warehouse})$, materials (blanks, component parts and folding etc.) $Material$ and ready products $Product$, as well as transport parameters $Transport$.

$$Warehouse =< D_{Warehouse}(x_{Warehouse}, y_{Warehouse}, z_{Warehouse}), Material, Product, Transport > \tag{32}$$

In this model, the parameter $Material$ can be shown with a set of materials:

$$Material = (material_1, material_2, ..., material_n)\ . \tag{33}$$

Similarly for products and transportation parameters:

$$Product = (product_1, product_2, ..., product_n), \quad (34)$$

$$Transport = (transport_1, transport_2, ..., transport_n). \quad (35)$$

Thus, all the introduced designations of the FIMS WS objects and the belonging transportation system form an information-logical model of the robotic system. The main purpose of the proposed model is to save current information about the state of FIMS objects and related systems, as well as to support the execution of queries about the objects properties that are included in the information-logical model description.

For example, for the workspace shown in fig. 1.5, the construction of an information-logical model will be formed based on the following input data.

There is a workspace with geometric dimensions of 70 x 25 x 10 m. It contains objects such as people, machines and equipment with various kinds of tools, storage, overhead stacker crane as a system for moving goods between two machines, or a machine and an equipment cabinet.

The machines used have certain overall dimensions (1.7 x 1.906 x 2.26 m for ANS machines, 1.78 x 2.2 x 1.675 m for ASM machines used in production).

Cabinets are equipped with geometric dimensions of 1.5 x 0.7 x 1.7 m. They contain both general purpose tools and specialized tools used on machine tools.

If the tool is heavy, then a stacker crane is used to move it between the tool cabinet and the machine (10 m).

Operations for changing the load, its movement, as well as tracking the machines are performed by a person.

After assembling the products, they are moved to the drives, from where a person, using a trolley, delivers them to the equipment warehouse.

It should be noted that the gaps between the objects of the workspace are very wide, and it is advisable to use mobile robots for transportation operations, which will significantly speed up the process.

Presentation of a flexible production site based on the developed model is shown in fig. 4.

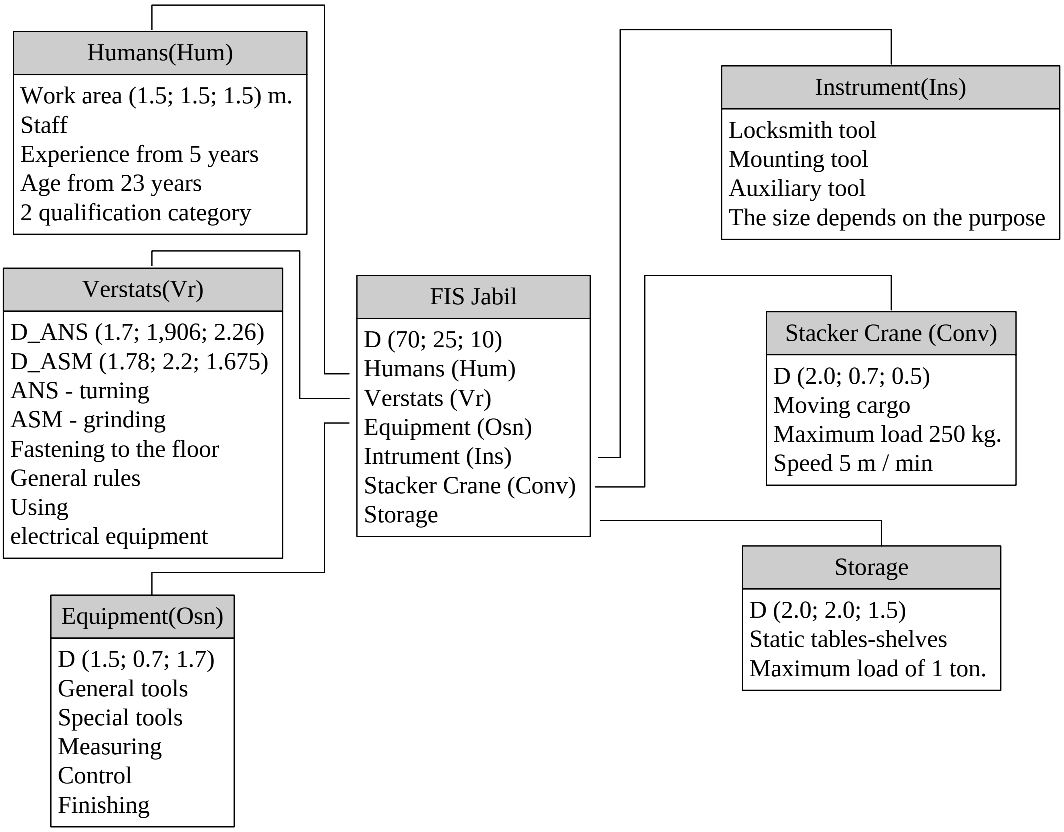

Fig. 4. Flexible production site based on the developed model

Proposed approach can describe basic properties of flexible manufacturing units, cells or areas. Composition of such descriptions can present background for development of automated control systems or their particular elements, including intelligent decision-making systems.

Conclusion

The actual problem of modern flexible integrated system (FIS), which follow the concept of Industry 4.0 is in large-scale supplement of informational support for production processes at all their stages. Such support can be supplied by introduction of information models, presenting elements of production systems. While consideration of robotic workspace models is still an actual task for researchers [11 - 13], new approaches, including visual sensoring [14 - 15] can give impacts to models of workspaces, especially in case of dynamic changes.

The FIS and robot's functioning in real-time mode also require information on production system, on robot itself, on all surrounding objects, making workspace of manufacturing robot.

Proposed article makes an analysis of existing approaches to simulate robotics workspaces, contains description of workspace models of informational type, which can be used to supply functioning of automated control systems, of intelligent decision-making systems for robots and other elements of FIS. The results of this work were used to supply execution of scientific project "Multi-purpose robotic platform with advanced manipulation possibilities" in the Kharkiv National University of Radio Electronics.

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ІНФОРМАЦІЙНІ МОДЕЛІ ДЛЯ ВИРОБНИЧИХ РОБОЧИХ ПРОСТОРІВ У РОБОТОТЕХНІЧНИХ ПРОЕКТАХ

Предметом дослідження статті є моделі робочого простору гнучких інтегрованих роботизованих систем. **Мета** роботи – побудова інформаційних моделей представлення робочого простору з метою подальшого використання у автоматизованих системах керування гнучкого інтегрованого виробництва. В статті вирішуються наступні **завдання:** провести аналіз представлення робочого простору під час розв'язання практичних завдань роботизованих систем різного типу, розглянути побудову інформаційних моделей представлення робочого простору інтелектуальних систем керування інтегрованим виробництвом, розглянути практичні приклади представлення інформації про робочий простір виробничих систем. **Методами** дослідження є теорія множин та теорія предикатів. Отримано наступні **результати:** проаналізовано основні особливості побудови інформаційних моделей робочого простору для розвязання завдань робототехніки різного типу, вказується на обмеженість існуючих підходів формального опису, на необхідність інтеграції моделей робочого простору із системами підтримки прийняття рішень, системами графічного та математичного моделювання інтегрованих систем; запропоновано теоретико-множинну модель подання інформації щодо процесів прийняття ріщень у гнучких інтегрованих роботизованих системах; розроблено інформаційно-логічну модель робочого простору мобільного робота, яка містить перелік об'єктів, враховує їх геометричні розміри, забезпечує зберігання параметрів у часі та просторі; розглянуто подання інформації у автоматизованиій системі керування гнучкого інтегрованого виробництва, що реалізує запропоновані моделі. **Висновки:** застосування моделей інформаційного типу у автоматизованих системах керування дозволить логічно об`єднати елементи гнучкого інтегрованого виробництва, забезпечити моніторинг стану технологічного обладнання у робочому просторі виробничих систем та у часі, здійснити формування цифрових двійників елементів робочого простору, забезпечити функціонування інтелектуальних систем підтримки прийняття рішень роботизованих систем різного типу, що дозволить покращити характеристики процесів керування виробництвом.

Ключові слова: інформаційна модель; робочий простір; мобільний робот; гнучка інтегрована система.

ИНФОРМАЦИОННЫЕ МОДЕЛИ ДЛЯ ПРОИЗВОДСТВЕННЫХ РАБОЧИХ ПРОСТРАНСТВ В РОБОТОТЕХНИЧЕСКИХ ПРОЕКТАХ

Предметом исследования статьи являются модели рабочего пространства гибких встроенных роботизированных систем. **Цель** работы – построение информационных моделей представления рабочего пространства для дальнейшего использования в автоматизированных системах управления гибкого интегрированного производства. В статье решаются следующие **задачи:** провести анализ представления рабочего пространства при решении практических задач роботизированных систем разного типа, рассмотреть построение информационных моделей представления рабочего пространства интеллектуальных систем управления интегрированным производством, рассмотреть практические примеры представления информации о рабочем пространстве производственных систем. **Методами** исследования являются теория множеств и теория предикатов. Получены следующие **результаты:** проанализированы основные особенности построения информационных моделей рабочего пространства для решения задач робототехники разного типа, указывается на ограниченность существующих подходов формального описания, необходимость интеграции моделей рабочего пространства с системами поддержки принятия решений, системами графического и математического моделирования интегрированных систем; предложена теоретико-множественная модель представления информации о процессах принятия решений в гибких интегрированных роботизированных системах; разработана информационно-логическая модель рабочего пространства мобильного робота, которая содержит перечень объектов, учитывает их геометрические размеры, обеспечивает хранение параметров во времени и пространстве; рассмотрено представление информации в автоматизированной системе управления гибкого интегрированного производства, реализующей предлагаемые модели. **Выводы:** применение моделей информационного типа в автоматизированных системах управления позволит логически объединить элементы гибкого интегрированного производства, обеспечить мониторинг состояния технологического оборудования в рабочем пространстве производственных систем и во времени, осуществить формирование цифровых двойников элементов рабочего пространства, обеспечить функционирование интеллектуальных систем для принятия решений систем разного типа, что позволит улучшить характеристики процессов управления производством.

Ключевые слова: информационная модель; рабочее пространство; мобильный робот; гибкая интегрированная система.

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