IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 1 Ser. V (Jan. - Feb. 2019), PP 61-67
www.iosrjournals.org

Development of an Information Model for Industrial Robots Actuators

Rami Matarneh[1], Svitlana Sotnik[2], Zhanna Deineko[3], Vyacheslav Lyashenko[4]
[1]*Department of Computer Science, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia*
[2]*Department of Computer-Integrated Technologies, Automation and Mechatronics, Kharkiv National University of RadioElectronics, Kharkiv, Ukraine*
[3]*Department of Media Systems and Technology, Kharkiv National University of RadioElectronics, Kharkiv, Ukraine*
[4]*Department of Informatics, Kharkiv National University of RadioElectronics, Kharkiv, Ukraine*
Corresponding Author: Rami Matarneh

Abstract: *This work aims to develop a classification model for drives actuators features depending on their feature. The proposed model consists of nine levels that include the most common actuators, which in turn will facilitate easy identification of relationships and ease of finding alternatives. On the basis of the proposed classification, an information model of actuator alternatives has been created, which reflects key information about them. The created model will provide an opportunity to reduce the design time of the actuators.*

Keywords: *Information, Model, Actuators, Industrial, Robots.*

Date of Submission: 22-02-2019 Date of acceptance: 08-03-2019

I. Introduction

Nowadays, technical progress relies heavily on the development of rapid robots because it allows us to introduce innovative automation tools. Robotics is constantly expanding its borders [1-5]. Using robots, companies of any scale not only follow the automation style with the help of latest technologies, but they get highly efficient and flexible production, increase its reliability and versatility. Also in the age of energy-saving technologies, there is a need to create more economical robotic systems. Partially, the solution to this problem becomes real due to the reduction of actuators power consumption reduction.

Actuators that are used in industrial robots impose quite stringent and specific requirements. Since the actuators are built into the executive robot systems, dimensions and weight of the actuators should be minimal. Robots actuators operate in non-established modes and with variable load. The process of actuators design includes of robot structural-kinematic scheme analysis, choice of layout actuators scheme, motors according to the mobility degree, kinematic chains calculation, gear mechanisms and their elements.

The choice of actuator type depends on the functional purpose of the robot. The main factors that determine the choice of actuators type for industrial robots are: purpose and conditions of operation, capacity and the necessary dynamic characteristics of the design, as well as control system type. Rational choice of actuator for a robot affects: speed, dimensions and weight of robot, power, etc.

II. Materials and Methods

2.1. Related Work

Many studies in the field of robotics are related to the actuators use. The use of robots is highly recommended for industries especially for safety and productivity reasons. Along with selection of numerous actuator designs, has been and remains an important task of optimizing them.

In [6] a new low cost, low power consumption, light weight, and silent method for actuation for robots and other motion control devices are investigate. In this work presents the ability of electro active polymer to provide higher power density for robot actuation over conventional approaches. Laboratory tests by DARPA compared electroactive polymer with conventional electromagnetic methodologies as well as shape memory alloy and piezo solutions. Electrical and hydraulic actuators considered in [7]. Actuators features which control hydraulic fluid flow and direction. This study reviewed revolute joints of robot. The joints of the arm are based on two high performance rotary type hydraulic actuators. Base task of this work is obtaining high speeds and torques.

In [8] a fault diagnosis approach for robotic manipulators, subject to faults of the joints driving systems, is developed. A model-based diagnostic observer is adopted to detect, isolate and identify failures. Compensation of unknown dynamics, uncertainties and disturbances is achieved through the adoption of a class of neural interpolators, the support vector machines and trained off-line. In [9] presents a methodology an integrated analysis tool for an industrial robot is developed combining dynamic and geometric models in a parametric design approach. An optimization case is conducted to visualize the automation capabilities of the proposed framework, and enhance the design for modular industrial robots. In [10] by altering values ranging from 1 to 15 represented different actuator choices for robots are reviewed. In [11] a review of variable impedance actuators. This paper presents an overview of the different VIAs developed and proposes a classification based on the principles through which the variable stiffness and damping are achieved.

2.2. The Main Features of Actuators for Industrial Robots Classification

Based on analysis of existing AC structure and parameters [12-14], a nine-stage classification of AC is proposed, which is shown in Fig. 1.

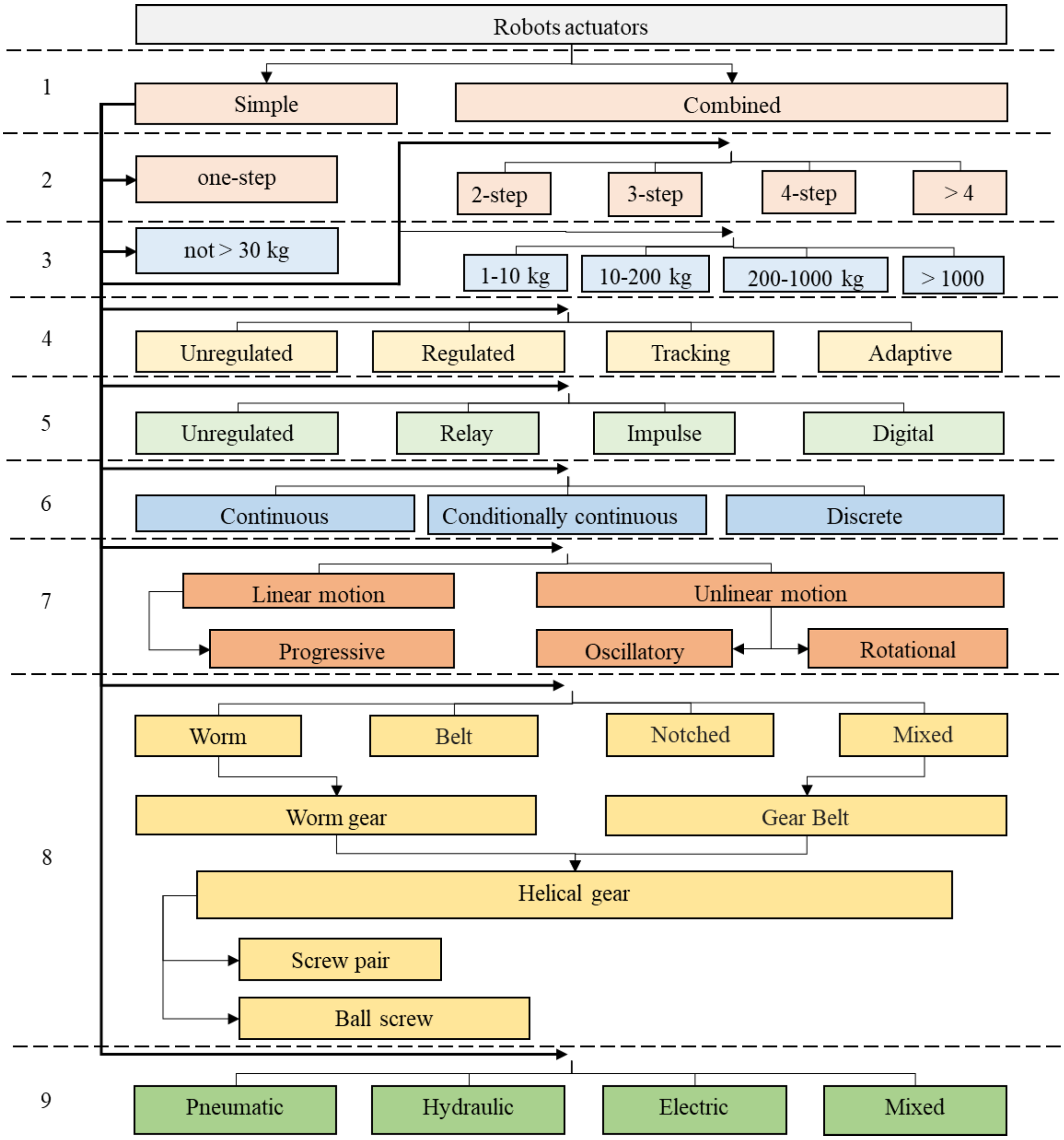

Fig. 1: General classification of actuators, taking into account the industrial robots characteristics

During the analysis of modern actuators features, it is proposed (level 1) to classify them into simple ones (which are mainly used to perform relatively simple operations, for example, painting, etc.) and combined AC (which perform more complex operations, for example, moving parts and blanks, loading - unloading, welding seams, cutting operation with tool movement along a complex trajectory).

Simple actuators are based on pneumatic, hydraulic, power cylinders.

Level 2 – classification according to mobility degree. At this level, simple ACs are proposed to be classified as one-step, and combined ones will then be divided into 2, 3, 4, and more than four mobility degrees.

Level 3 – classification by load. At this level, let the simple ones include actuators designed to work with a load of more than 30 kg. With regards to combined, they can be "light" 1-10 kg, "Average" 10-200 kg, "Heavy" 200-1000 kg and super heavy, when load exceeds 1000 kg.

Level 4 – controllability degree.

Level 5 – by type of control device. The control device AC can be: continuous, relay, pulse or digital.

Level 6 – by impact degree, that is, by rotation method. All ACs are divided into: rotating continuously, conditionally-continuous and discretely.

Level 7 – by type of movement. AC can be divided into: linearly moving (translational motion) and nonlinear, that is, rotational and oscillatory motion.

Level 8 – on transfer mechanism. AC are divided into: worm, leather, gear and mixed transmission mechanisms.

Level 9 – type of energy used. There are pneumatic, hydraulic, electric and mixed AC.

Thus, a general classification of AC for industrial robots is presented, which consists of nine levels of detail and is a prerequisite for creating an AC information model, which includes the main factors that determine the choice of AC type.

The developed classification allows for a more detailed study of actuators use, as well as their features.

Thus, the classification is presented, which consists of nine levels, the most common AC, allows you to determine their relationship. This makes it possible to study in more detail the structure of explosives, as well as their parameters.

III. Results

3.1. Information Model of Actuators for Industrial Robots

The information model is important because it allows you to formalize key data about the actuators for the convenience of achieving practical goals.

According to developed classification (Fig. 1), a general view of simple and combined AC construction can be represented as:

$$Dr =< E_i^j, O >, \qquad (1)$$

where E_i^j – structural units of construction AC set;

i – main AC kinds, i = 1…2 (1 – simple, 2 – combined);

j – main AC types, j = 1…4 (1 – pneumatic actuators (PA), 2 – hydraulic actuators (HA), 3 – electric actuators (EA), 4 – mixed actuators (MA));

O –relationships set between the structural elements (SE).

Imagine information about the actuators in form of an information model:

$$E_t^j =< GI_t, EP_t, GE_t >, \qquad (2)$$

where GI_t – general information that affect the AC key characteristics;

EP_t – properties of AC elements;

GE_t – geometry (relative position) of AC structural elements. The actuators themselves are located: in a single unit, on moving parts, a combined layout.

Then general information GI_t can be described by such dependencies:

$$GI_t =< DM_{t_n}, CC_{t_n}, DC_{t_n}^j, TC_{t_n}^j, WT_{t_n}^j, MnT_{t_n}^j,$$

$$TrM_{t_n}^j, GA_t^j, MS_t^j, PW_t^j, PA_t^j >, \qquad (3)$$

where DM_{t_n} – robot mobility degree, which affects number of engines and total power of a simple AC for n = 1 is the number of mobility degrees;

CC_{t_n} – load capacity, which affects the AC power at n = 1 ... N (N is the range in which the load mass);

$DC^{j}_{t_n}$ – controllability degree of j-th AC type with n = 1 ... 4 (1 – unregulated, 2 – regulated, 3 – tracking, 4 – adaptive);

$TC^{j}_{t_n}$ – control device type of j-th AC alternative type for n = 1 ... 4 (1 – continuous, 2 – relay, 3 – pulsed or 4 – digital);

$WT^{j}_{t_n}$ – degree of impact, that is, the rotation method of j-th AC type, when n = 1 ... 3 (1 – continuous, 2 – conditionally continuous, 3 – discrete);

$MnT^{j}_{t_n}$ – movement type of j-th AC alternative type with n = 1 ... 3 (1 – linear movement for actuating the actuator, 2 – non-linear (rotary), 3 – non-linear (oscillatory));

$TrM^{j}_{t_n}$ – transfer mechanism of j-th AC type with n = 1 ... 4 (1 – worm, 2 – belt, 3 – gear, 4 – mixed);

GA^{j}_{t} – dimensions of j-th AC alternative type;

MS^{j}_{t} – mass of j-th AC alternative type;

PW^{j}_{t} – power of j-th AC alternative type;

RB^{j}_{t} – reliability of j-th AC alternative type;

PA^{j}_{t} – positioning accuracy of j-th AC alternative type (inaccurate positioning most often arises due to errors in manipulating the generalized coordinates programmable manipulator corresponding to a given position of gripping device).

Properties of AC elements EP_t can be represented as:

$$EP_t = \langle ME^{j}_{t}, SE^{j}_{t} \rangle, \tag{4}$$

where ME^{j}_{t} – elements mass of j-th AC alternative type;

SE^{j}_{t} – elements size of j-th AC alternative type (as elements are motor, AC device control and etc.).

The geometry (location) of AC structural units GE_t will be represented as:

$$GE_t = \langle PL^{j}_{t}, LC^{j}_{t} \rangle, \tag{5}$$

where PL^{j}_{t} – location of elements in j-th AC alternative type;

LC^{j}_{t} – elements location coordinates in j-th AC alternative type.

Information models of AC designs reflect the AC composition for development of a mathematical model in the process of creating a automated design module of AC. In developed model there is data about the elements, their properties, mutual relations and connections.

3.2. Discussion of Information Model Application Results

Having the proposed information model (2) to determine the key parameters of AC, studies have been conducted of parameters such as capacity, mobility, positioning accuracy, speed, size, reliability, supply voltage, etc.

The results of analysis are shown in Table 1, where the general characteristics of pneumatic, hydraulic and electric actuators for linear motion are compared.

Thus, PA is simpler than hydraulic and electric actuators, which provide advantages in initial costs and maintenance.

It is determined that PA and HA methods of energy transfer usually provide more power in a smaller space, so small pneumatic cylinders can be used to provide the necessary high clamping or positioning force needed to hold the product in certain machining and other applications.

Table 1: Robot characteristics

Characteristics	PA	HA	EA
Complexity structures	Simple	Medium	Medium / high complexity
Allowable power	High	Very high	High
Size	Small size / strength	Small size / strength	Average size / strength
Control	Simple Valves	Simple Valves	Electronic Controller
Positioning accuracy	Good	Good	Excellent
Speed	Fast	Low	Fast
Actuator cost	Low	High	High
Maintenance cost	Low	High	Low
Utilities	Compressor / power / pipes	Pump / Power / Pipes	Only power
Efficiency	Low	Low	High
Reliability	Excellent	Good	Good

Power control is usually easier with pneumatics and hydraulics than with electrical systems. Simple control valve, regulator, as a rule, it is necessary to control the direction, speed and force of cylinder. An EA often needs an electronic controller, several I/O points, communication cables and, possibly, feedback to sensor, as well as more complex programming of automation system. EAs do not have pipelines, as they "feed" with energy. In the GA low speed, because the working medium is liquid.

According to the proposed classification in Fig. 1, simple actuators designed to work with a load of more than thirty kilograms. With regards to combined, they can be "light" 1-10 kg, "average" 10-200 kg, "difficult" 200-1000 kg and extra heavy when the load exceeds 1000 kg.

Consider the parameters of load capacity and degree of robot mobility for PA, because during the analysis it was found that most often load capacity for the PA from 10 kg to 20 kg, and degree of mobility – 2 ... 3. Therefore, the robots models with a greater degree mobility and greater carrying capacity. Data for research are shown in Table 2.

Table 2: Parameters for robots with PA

№	Actuators subclass	Load capacity, kg	Mobility degree	Model of the robot
1	PA	10	5	KM10Z42.03
2		10	4	PRP-5
3		16	6	PR-16P
4		20	6	RIMR-402
5		35	4	SR-25 (Shinko Electric Co)
6		45	4	Transiva (BR Talore)

During the analysis, it was determined that GAs are used in works of average carrying capacity. Therefore, the following data was selected for the study of GA, which are shown in Table 3.

Robots with a load capacity of more than 20 kg and more than 4 mobility degrees were selected.

Table 3: Parameters for robots with HA

№	Actuators subclass	Load capacity, kg	Mobility degree	Model of the robot
1	GA	20	5	LM.20Z46.01
2		25	4	MTE-55
3		25	6	RB-50 (Yasui Sangvo Co.)
4		40	7	Pirin-521
5		45	4	Transiva (BR Talore)
6		50	5	RBH-50 (Vasui Sangyo Co.)

Based on the data from Table 2 in Fig. 2, we plotted the load-bearing capacity and degrees of robots mobility with PA Fig. 2a, for the data of GA from Table 3 in Fig. 2b.

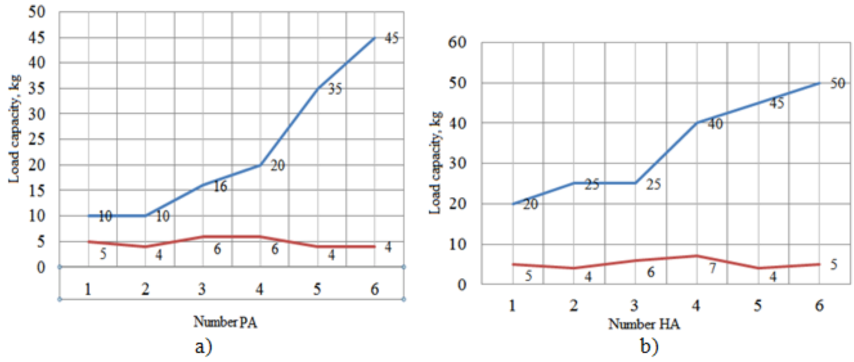

Fig. 2: Load charts and mobility degrees of industrial robots

Most often, the mobility degree for the EA is from 3 to 6, therefore we will consider this range, and the load capacity can usually be up to 20 kg, therefore, we will analyze these parameters taking into account their energy used type. The data for research are given in Table 4. A robot with an EA that has a payload capacity of more than 20 kg was chosen as the fifth option.

Table 4: Parameters for robots with EA

№	Actuators subclass	Load capacity, kg	Mobility degree	Model of the robot
1	EA	0,02	2	MPU-901
2		1,5	5	Pragma-A3000 (DEA)
3		5	6	Univesel-5
4		12	6	Robotek-1 (Liebherr)
5		25	6	Robotek-2 (Liebherr)

Let's analyze the parameters for robots with mixed actuators. Data for the study are shown in Table 5.

Table 5: Parameters of mixed- actuator robots (MA)

№	Actuators subclass	Load capacity, kg	Mobility degree	Model of the robot
1	E – P	1	5	RF-1001C
2		2	3	HFR-1
3		5	4	Itekar
4	P – H	5	4	3388-1
5		6	4	3388-2
6		20	4	3388-3

Based on the data from Table 4 in Fig. 3, the graphs of load-carrying capacity and degrees of robots mobility with electronic signature are plotted. Fig. 3 a, b, graphs for robots with joint ventures.

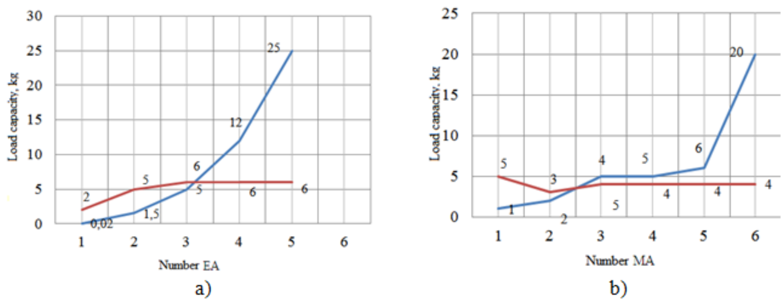

Fig. 3: Load charts and mobility degrees of industrial robots

The choice of actuator type depends not only on robots functional purpose, on load capacity and degree of robots mobility, therefore, above studies were carried out, which showed that in some cases with low mobility degrees, the load capacity was not low. Although the degree of mobility determines the carrying capacity of entire manipulator and it is necessary to unload the reasons as much as possible in order to provide the required positioning accuracy, but in robots designed for working with large loads there are not always many mobility degrees, as can be seen from Table 2 and Table 3.

IV. Conclusion

In this work, a actuators classification was proposed taking into account the industrial robots characteristics, which allows for a more detailed study of issues of the actuators use, as well as their specificity. The developed classification differs from the existing ones in that it is considered from the side of performing operations and is divided into simple and combined, where simple is a set of actuators used for relatively simple operations, and in the other case – combined. Accounting for such AC features affects the decision-making process at the chosen power and positioning accuracy, because these parameters are one of the key for industrial robots.

The proposed information model of AC alternatives reflects basic information. The model differs from the existing ones in that all ACs are considered from the point of view the operations performed by the robot complexity and the load mass, affecting speed, accuracy and power, which are the main AC parameters.

Thus, the ability to build an information model is essential in the process of computer-aided design and creation of computer-aided design systems, since each design stage can be associated with its own model and thus avoid unreasonable complication of the design task.

A study was also carried out of load capacity and industrial robots mobility degree, which showed that work with the HA was dominant, although they had a high cost, and speed of moving fluid of hydraulic actuators was relatively small.

Acknowledgements

The authors would like to acknowledge the keen support for this work of the Department of Computer Science, Prince Sattam Bin Abdulaziz University, Al-Kharj, Saudi Arabia and also the Department of Informatics, Kharkov National University of RadioElectronics, Kharkiv, Ukraine [2-5, 15-18].

References

[1]. Connell, J. H. (2012). *Minimalist mobile robotics*. Elsevier.
[2]. Maksymova, S., Matarneh, R., Lyashenko, V. V., & Belova, N. V. (2017). Voice Control for an Industrial Robot as a Combination of Various Robotic Assembly Process Models. *Journal of Computer and Communications*, *5*(11), 1-15.
[3]. Maksymova, S., Matarneh, R., & Lyashenko, V. V. (2017). Software for Voice Control Robot: Example of Implementation. *Open Access Library Journal*, *4*(08), 1-12.
[4]. Matarneh, R., Maksymova, S., Deineko, Z., & Lyashenko, V. (2017). Building Robot Voice Control Training Methodology Using Artificial Neural Net. *International Journal of Civil Engineering and Technology*, 8(10), 523–532.
[5]. Matarneh, R., Maksymova, S., Zeleniy, O., & Lyashenko, V. (2018). Voice Control for Flexible Medicine Robot. *International Journal of ComputerTrends and Technology*, 56(1), 1-5.
[6]. Norrlof, M. (2002). An adaptive iterative learning control algorithm with experiments on an industrial robot. *IEEE Transactions on robotics and automation*, *18*(2), 245-251.
[7]. Liyanage, M. H., Krouglicof, N., & Gosine, R. (2009). Design and control of a high performance SCARA type robotic arm with rotary hydraulic actuators. In *Electrical and Computer Engineering, 2009. CCECE'09. Canadian Conference on* (pp. 827-832). IEEE.
[8]. Caccavale, F., Cilibrizzi, P., Pierri, F., & Villani, L. (2009). Actuators fault diagnosis for robot manipulators with uncertain model. *Control Engineering Practice*, *17*(1), 146-157.
[9]. Tarkian, M., Ölvander, J., Feng, X., & Petterson, M. (2009, January). Design automation of modular industrial robots. In *ASME 2009 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference* (pp. 655-664). American Society of Mechanical Engineers.
[10]. Ölvander, J., Tarkian, M., & Feng, X. (2011). Multi-objective Optimisation of a Family of Industrial Robots. In *Multi-objective Evolutionary Optimisation for Product Design and Manufacturing* (pp. 189-217). Springer, London.
[11]. Vanderborght, B., Albu-Schäffer, A., Bicchi, A., Burdet, E., Caldwell, D. G., Carloni, R., ... & Garabini, M. (2013). Variable impedance actuators: A review. *Robotics and autonomous systems*, *61*(12), 1601-1614.
[12]. Boldea, I., & Nasar, S. A. (2016). *Electric drives*. CRC press.
[13]. Engelberger, J. F. (2012). *Robotics in practice: management and applications of industrial robots*. Springer Science & Business Media.
[14]. Choi, S. B., & Han, Y. M. (2016). *Piezoelectric actuators: control applications of smart materials*. CRC Press.
[15]. Lyashenko, V., Matarneh, R., & Kobylin, O. (2016). Contrast modification as a tool to study the structure of blood components. *Journal of Environmental Science, Computer Science and Engineering & Technology*, *5*(3), 150-160.
[16]. Sotnik, S., Matarneh, R., & Lyashenko, V. (2017). System model tooling for injection molding. *International Journal of Mechanical Engineering and Technology*, *8*(9), 378-390.
[17]. Drugain, C. V. A., Ahmad, M. A., & Lyashenko, V. (2018). Comparative Aspects of the Temporal Characteristics of the Production of Various Plastic Products. *Analele Universitatii'Eftimie Murgu'*, *25*(2), 17-24.
[18]. Drugarin, C. V. A., Lyashenko, V. V., Mbunwe, M. J., & Ahmad, M. A. (2018). Pre-processing of Images as a Source of Additional Information for Image of the Natural Polymer Composites. *Analele Universitatii'Eftimie Murgu'*, *25*(2), 11-16.

Rami Matarneh. "Development of an Information Model for Industrial Robots Actuators." IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 16, no. 1, 2019, pp. 61-67