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Interesting Applications of Mobile Robotic Motion by using Control Algorithms

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ABSTRACT

Robots are widely used in various fields of production. These complex technical devices are able to facilitate the work of man. Among the varieties of robots, it is necessary to highlight mobile robots. The ability to move expands the ability of robots to perform more complex tasks. The basis of mobile robots is their navigation system. Such a system consists of various algorithms that ensure the fulfillment of tasks. Among these algorithms, it is worth highlighting: robot control when avoiding obstacles, finding a directional path, general robot motion control. These issues are considered in this paper.

Key words: Control Algorithms, Mobile Robot, Navigation System, Robot Movement, Common Control, Obstacle Avoidance.

1. INTRODUCTION

Robots are complex technical devices that are capable of performing various functions. These functions are intended to help a person, facilitate the work of a person. Modern robotic systems are able to perform their functions in various conditions. This allows the use of robotic systems in various industries.

A special place among robotic systems is occupied by mobile robots [1]. Such systems carry out a targeted movement to perform their functions. The ability to move expands the ability of robots to solve tasks that they can perform.

To realize the possibilities of movement, a mobile robot has a navigation system. Such a system has a set of algorithms that are designed to move in space. This is achieved due to the presence of various sensors that perceive the environment. The navigation system processes information from sensors and makes the necessary decisions. For this, various methods, technologies, theories are used: adaptive control theory, pattern recognition theory, data normalization methods, neural systems theory, artificial intelligence theory, general and special information technologies [2]-[4].

It is important to control the motion parameters of the robot. Algorithms for controlling the robot while avoiding obstacles, finding a directional path, and the concept of general motion control occupy a key place among such parameters of the movement of the robot. These questions determine the basis for research in this work.

2. RELATED RESEARCH

Robot movement algorithms are the focus of relevant research.For example, M. A. Yakoubi and M. T. Laskri research genetic algorithms for controlling the movement of robots [5]. In this case, special attention is paid to algorithms of movement with obstacles.

S. V. Konstantinov, A. I. Diveev, G. I. Balandina and A. A. Baryshnikov conduct a comparative study of various robot movement algorithms [6]. Such a comparison is based on the optimization of the parameters of the overall control of the movement of the robot. Particular attention is paid to random search algorithms for the optimal path for movement.

In [7] algorithms for the movement of robots on flexible surfaces are considered. This makes it necessary to improve such algorithms taking into account the dynamics of the surface along which the robot moves.

In [8], the "Skeletonization" technique was proposed, based on the distance transformation, which can be performed in linear time. Since in space they always tend to approach the "true skeleton", that is, two requirements must be fulfilled: topological (to preserve the topology of the source object) and geometric (forcing the "skeleton" to be in the middle of the object and invariance under the most important geometric transformation, including translation, rotation and scaling). Thus, for the effective movement of the robot two conditions must be satisfied.

The proposed in [9] research is based on a practical approach to the creation of motion trajectories with continuous control for mobile robots. Two key problems of robot movement planning are considered; continuity of the path and limitation of the maximum curvature for nonholonomic robots. The path parameters are formulated with respect to the limitations of the robot. To represent the path, B-splines are used. However, the essential difference this technique lies in the complexity of plotting the curves, complexity of calculating the distance from the robot to the curve, which makes such curves unsuitable in terms of their use in the algorithms for controlling the mobile robot.

The study [10] considers the issue of testing hypotheses for detecting obstacles. Planning the movements of the robot, this must bypass the obstacles. The problem of computer vision is solved in the work – detection of semantically important objects and estimation of their location using the hypothesis-test method. Although the main advantage is its simplicity and the method is designed for a "rare" arrangement of obstacles. When space is filled with objects, attempts to avoid a collision with one obstacle usually lead to a collision with another. And also in [10], the modification operation of the proposed path can be very difficult.

A methodology for route planning based on the parallel evolutionary artificial potential (PEAPF), which can also obtain optimal solutions, is described in [11], but its processing time can be prohibitive in complex environmental situations. Also, the distinguishing feature of the technique described in [11] is the complexity of the navigation function formation. Motion algorithm which is based on a vision system developed in [12]. This algorithm is based on combined fuzzy image processing and bacterial algorithm. Algorithms for collision-free navigation of mobile robots in complex cluttered environments are also considered in [12].

In [13], the problems of detecting obstacles and the algorithm for avoiding obstacles were considered, modeling of a map of the area. A new algorithm for describing a map of the area is also proposed. This improves the efficiency of obstacle avoidance algorithms. Moreover, the construction of a safe path is based on Bezier curves.

Thus, various issues related to controlling the movement of a mobile robot are relevant. At the same time, special attention should be paid to circumventing obstacles and the overall control of the movement of the robot.

3. CONTROL ALGORITHM FOR OBSTACLES BYPASSING THE ROBOT

Various algorithms can be used to provide control of the robot's movement and obstacle avoidance [14], [15]. At the same time, one of the promising algorithms is the directional search path algorithm.

Consider an algorithm for directing the search for a path to avoid obstacles from point 0 to the final one G, characterized by the lack of information about the surface parts remote from the robot by more than n cells of the matrix A.

For each of the m directions of robot movement, possible at the given moment, the total weight Pi of the given direction is determined, defined by the formula [15].

$$P_i = \sum w_k \times P_{ki} \quad (1)$$

where w_k is the weight of the estimate; P_{ki} - evaluation of the i-direction by the evaluation unit (hereinafter it is Block 1 - Block 5).

The control algorithm for traversing obstacles by the robot includes an algorithm for directional path search, which consists of: the possibility of the robot movement direction (Figure 1); the relief model, which is displayed by the matrix A (Figure 2); the structural scheme of the algorithm (Figure 3).

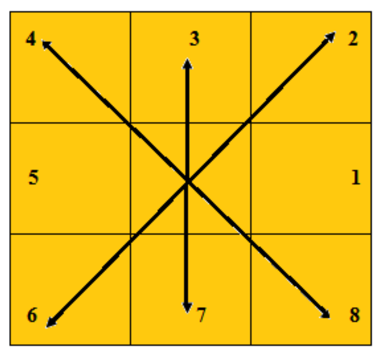

Figure 1: Some possibility of the robot movement direction

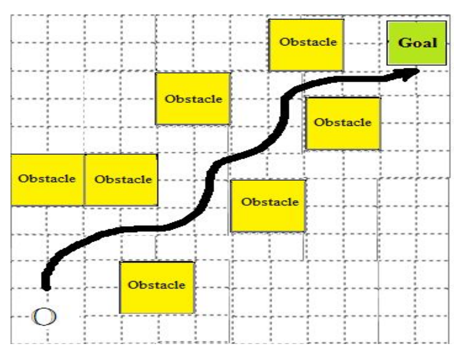

Figure 2: Robot motion environment model

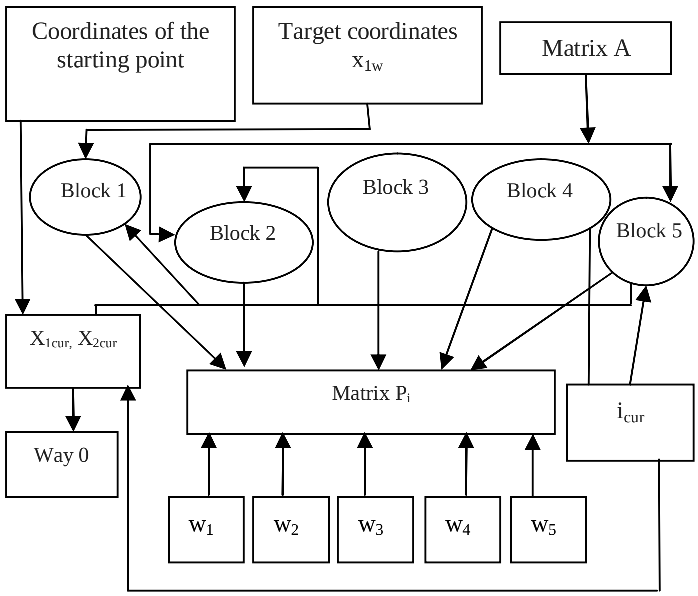

Figure 3: Structural diagram of the obstacle avoidance algorithm

As the direction of the next step, the direction m, which received the greatest weight P_m , is selected. Block 1 highlights the direction to the goal; for estimating P_{1i} , the angle cosine between the direction to the goal from the given cell and the i-th direction is assumed. Thus, [16, 17]:

$$P_{1i} = \frac{(x_{1w} - x_{1cur}) \times \cos \pi / 4(i-1) + (x_{2w} - x_{2cur}) \times \sin \pi / 4(i-1)}{\sqrt{(x_{1w} - x_{1cur})^2 + (x_{2w} - x_{2cur})^2}}$$

where x_{1cur}, x_{2cur} – current robot coordinates; x_{1w}, x_{2w} – goal coordinates.

Weight w_1 determines the importance of maintaining the goal direction, with $w_1 < 0$ the robot tends to move away from the goal.

Block 2 allocates among the neighboring cells of matrix A cells occupied by obstacles, namely: $P_{2i} = 1$ if the cell $(x_{1cur} + \Delta x_{1i}, x_{2cur} + \Delta x_{2i})$ is occupied, and $P_{2i} = 0$ - otherwise; and Δx_{1i} - the displacement steps in the direction i.

Weight w_2 characterizes the ratio of the robot to the obstacles: when $w_2 < 0$ the robot avoids obstacles, at $w_2 > 0$ it tends to walk on the cells marked as an obstacle.

Block 3 defines random estimates $P_{3i} = z$ in which random numbers are chosen with uniform probability on the interval (0, 1).

Weight w_3 determines the degree of chaos in the robot behavior and can change in the process of finding a way in difficult situations.

In the case of a dead end, the last M mages did not lead to a reduction in the distance to the target [16, 17]

$$r_{xa} = \sqrt{(x_{1w} - x_{1cur})^2 + (x_{2w} - x_{2cur})^2}, \qquad (2)$$

weight w_3 gradually increases until the direction search at each step becomes almost random. Then the probability of an object falling onto any unoccupied cell is described by an equation such as the diffusion equation, and for any form of deadlock, the robot will eventually find a way out.

Block 4 determines the robot, inertia P_{4i} for the direction $i0$ in which the previous step was taken, $P_{4i} = \frac{1}{2}$ - for directions that differ from $i0$ on $\pm\frac{\pi}{4}$, and $P_{4i} = 0$ - for the other directions. When $w_4 > 0$ the robot tends to turn smoothly and withstand the motion along a straight line, at $w_4 < 0$ the robot scampering from side to side and inclined to sharp turns.

Block 5 simulates "near-foresight" and gives a signal about the simplest dead-end situations in one step.

Evaluation $P_{5i} = 1$, if after a step in the i-th direction the robot has to rotate by an angle greater than $\frac{\pi}{4}$, and $P_{5i} = 0$ if after the step in the i-th direction it is possible to continue the movements without turning more than on $\frac{\pi}{4}$. Thus, when $w_5 < 0$ "warns" the robot from a perpendicular approach to the wall and cornering.

Weight w_5 characterizes the robot's caution.

The result of the methods used above is the mobile robot navigation with the help of technical vision together with the drawing up of the environment map.

At the same time, as noted above, the robot first constructs the map of the external environment, moving from the starting point (Figure 2) in accordance with the proposed methodology.

As a result, a map is formed (Figure 2), where the white areas are marked with free areas for moving the robot, in yellow – the areas occupied by the obstacle and in green – the target area.

Then the robot is placed at the starting point of the movement. Its task is to find the optimal (in the sense of the trajectory length) path to the goal along the trajectory (Figure 2), which is obviously the most optimal of all trajectories leading to the goal.

4. GENERALIZED CONTROL SYSTEM

A generalized scheme for the operation of the control system is shown in Figure 4.

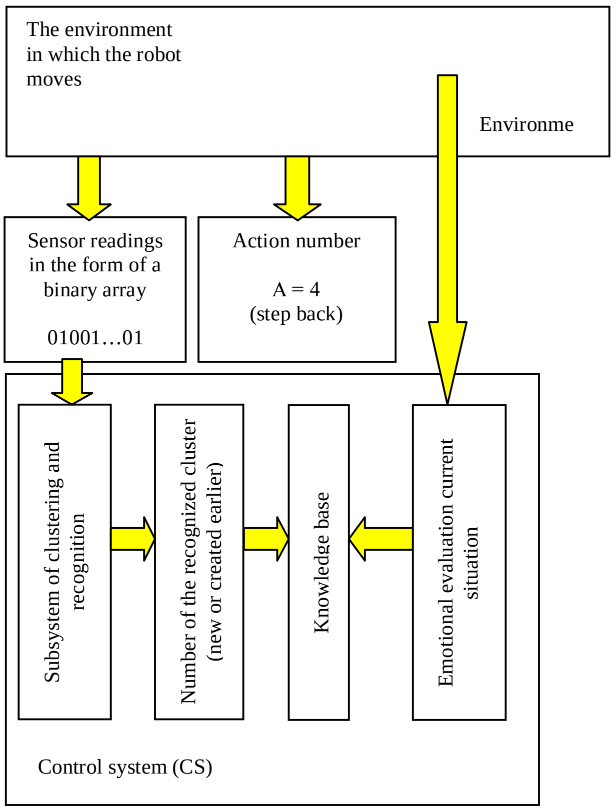

Figure 4: Scheme of mobile robot functioning

At the beginning of each control cycle, the readings of all sensors are converted to a binary form, where "1" means an obstacle in the sector, "0" means no obstacle that is combined into a binary vector.

The position of the individual data components in this vector does not matter, since the control system itself learns to understand what the particular data means. The advantage of the technique is the data homogeneity, which affects the independence of the system operation algorithm both from the specifics of the sensors used and from the nature of the input information.

The binary array obtained in this way arrives at the input of the dynamic clustering and recognition subsystem. The task of the dynamic clustering subsystem is to merge the data into clusters directly in the process of control object (CO) life. This is its fundamental difference from the commonly used algorithms for solving clustering problems, when all possible input vectors are provided immediately.

At the subsystem output, the number of the newly created or recognized cluster is formed, which can be called the "image". If this image has not yet been encountered by the CS before, then the control system can choose any of the actions possible for CO, since the control system does not initially have any rules of behavior. If the image has already been encountered, then it is necessary to take into account the knowledge accumulated earlier about the actions of the control object in a similar situation and the results to which they resulted. This task is solved using the subsystem "knowledge base". This task is solved using the subsystem "knowledge base". Knowledge base provides storage and use of "knowledge" in the form of form triples "image" - "action" - "result".

The CO interacts with the environment through actuators, which the CS activates with its output commands - actions.

In this case, the "action" is one of the six possible movements of the platform carried out by the wheel drive.

As in the case of sensors, the CS does not initially know what this or that movement leads to, and begins to understand this only in the learning process. After doing any action, the CO is in a new situation.

In the CS, there is an " emotions apparatus" that, on the basis of new sensor readings, gives an integral evaluation of the robot's state at the current time (if as a result of the action taken a collision with the obstacle occurred, then this is "bad," and if not, it is "good") .

SU initially understands "what is good, what is bad", that is, can evaluate - the result of the performed action.

Thus, the basic principle of the work: if there is a record in the knowledge base for any recognized image O_1 that the action A_1 resulted in a collision and the action A_2 did not result, then the CS already possesses the necessary knowledge to bypass the obstacle that has come into view of the CO.

Therefore, in the process of CO operating, the task of maximizing the "emotional" estimate is solved, which allows solving global survival problems (for example, avoiding collisions) of the CO and the accumulation of knowledge.

In flexible computerized production, the motion control algorithm can also be used as a technology, as an example:

– a robot-cart that can move on a different surface, let it be a surface with a pronounced line of a certain color, the robot with the help of sensors determines this line and moves along it;

– by electromagnetic tape – the electric current is applied to the magnet and the robot moves, following this tape;

– with the help of a laser, due to which the robot is able to detect obstacles and bypass them, plotting the optimal route; or on the principle of a children's railway [18].

For an example, we also consider the algorithm for controlling electrocircuit (EC). The main task of the EC is to ensure the orientation and transportation of robotic objects in the space served. The algorithmic organization of this provision is based on flexible programming of the movement in accordance with the basic modes of EC operation.

The execution of the "Program" mode begins with the route transmission, its number and length through the optoelectronic communication unit from the operative memory of the mini-computer to the operational memory of the on-board microcomputer.

In the "training" mode, the recording of the program in the RAM of the on-board machine and starting is carried out from the EC control panel. Execution of the program and training implements algorithms [17], [18]:

– development of control actions (drive control);
– management of the sensor system;
– route analysis;
– passing barriers;
– precise positioning;
– discharge of EC.

In the "Manual control" mode, the remote controller is used to move the EC.

The technical implementation of the EC moving task on the route is carried out using a combined tracking system.

An analysis of the actual production conditions and the requirements for providing increased flexibility of the EC make it possible to conclude that the three-channel tracking system of its route is relevant. This algorithm is simple, efficient and can be used in robotic complexes.

5. CONCLUSION

The effective use of mobile robots depends on their motion control system. Such a system is the basis for the navigation of a mobile robot. Therefore, an important issue is the development of various algorithms for controlling the movement of the robot.

An algorithm for directional path search is considered, which consists of: the possibility of the robot movement direction; model of relief, which is proposed to display the matrix; structural scheme of the algorithm. The result of these techniques is the study of the environment in order to compile its map and find the goal.

It is shown that the presented algorithms and methods are efficient and effective for creating a navigation system for a mobile robot, since it is possible to train and effectively manage the control object.

The resulted control system of a mobile robot while traversing obstacles allows to reduce the time costs for making a decision, as well as to simplify the algorithm for choosing the response of the system when recognizing the situation.

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REFERENCES

1. M. Ayaz, T. Sinelnikova, S. K. Mustafa, and V. Lyashenko. **Features of the Construction and Control of the Navigation System of a Mobile Robot**, *International Journal of Emerging Trends in Engineering Research*, Vol. 8, no. 4, pp. 1445-1449, 2020. https://doi.org/10.30534/ijeter/2020/82842020
2. M. Ayaz, I. Tvoroshenko, J. H. Baker, and V. Lyashenko. **Computational Complexity of the Accessory Function Setting Mechanism in Fuzzy Intellectual Systems**, *International Journal of Advanced Trends in Computer Science and Engineering*, Vol. 8, no. 5, pp. 2370-2377, 2019. https://doi.org/10.30534/ijatcse/2019/ 77852019
3. A. M. Babker, A. E. A. Altoum, I. Tvoroshenko, V. Lyashenko. **Information technologies of the processing of the spaces of the states of a complex biophysical object in the intellectual medical system health**, *International Journal of Advanced Trends in Computer Science and Engineering*, Vol. 8, no 6, pp. 3221-3227. https://doi.org/10.30534/ijatcse/2019/89862019
4. R. Matarneh, S. Maksymova, Zh. Deineko, and V. Lyashenko. **Building Robot Voice Control Training Methodology Using Artificial Neural Net**, *International Journal of Civil Engineering and Technology*, Vol. 8, no. 10, pp. 523-532, 2017.
5. M. A. Yakoubi,and M. T. Laskri, M. T. **The path planning of cleaner robot for coverage region using genetic algorithms**, *Journal of innovation in digital ecosystems*, Vol. 3, no. 1, pp. 37-43, 2016. https://doi.org/10.1016/j.jides.2016.05.004
6. S. V. Konstantinov, A. I. Diveev, G. I., Balandina, and A. A. Baryshnikov. **Comparative research of random search algorithms and evolutionary algorithms for**

the optimal control problem of the mobile robot, *Procedia Computer Science*, Vol. 150, pp. 462-470, 2019. https://doi.org/10.1016/j.procs.2019.02.080

7. X. Wu, J. Liu, Y. Zhou, Q. Lv, and C. Hu. **Movement control and attitude adjustment of climbing robot on flexible surfaces**, *IEEE Transactions on Industrial Electronics*, Vol. 65, no. 3, pp. 2618-2628, 2017. https://doi.org/10.1109/TIE.2017.2764870
8. N. Shalal, T. Low, C. McCarthy, and N. Hancock. **Orchard mapping and mobile robot localisation using on-board camera and laser scanner data fusion–Part A: Tree detection**, *Computers and Electronics in Agriculture*, Vol. 119, pp. 254-266, 2015. https://doi.org/10.1016/j.compag.2015.09.025
9. M. Elbanhawi, M. Simic, and R. N. Jazar. **Continuous path smoothing for car-like robots using B-spline curves**, *Journal of Intelligent & Robotic Systems*, Vol. 80, no 1, pp. 23-56, 2015. https://doi.org/10.1007/s10846-014-0172-0
10. N. Atanasov, B. Sankaran, N. J. Le, T. Koletschka, G. J. Pappas, and K. Daniilidis. **Hypothesis testing framework for active object detection**, *In International Conference on Robotics and Automation*, pp. 4216-4222, 2013. https://doi.org/10.1109/ICRA.2013.6631173
11. O. Montiel, R. Sepúlveda, and U. Orozco-Rosas. **Optimal path planning generation for mobile robots using parallel evolutionary artificial potential field**, *Journal of Intelligent & Robotic Systems*, Vol. 79, no. 2, pp. 237-257, 2015. https://doi.org/10.1007/s10846-014-0124-8
12. R. Al-Jarrah, M. Al-Jarrah, and H. Roth. **A Novel Edge Detection Algorithm for Mobile Robot Path Planning**, *Journal of Robotics*, Vol. 2018, pp. 1-12, 2018. https://doi.org/10.1155/2018/1969834
13. F. Hu, and Z. Xu. **Robot Path Planning Model of Target Gravity Optimal RRT Algorithm**, *Rev. Téc. Ing. Univ. Zulia*, Vol. 39, no. 7, pp. 403-414, 2016. https://doi.org/10.21311/001.39.7.50
14. S. Paul. **A Brief Insight into Nanorobotics**. *In Biomedical Engineering: Concepts, Methodologies, Tools, and Applications*, pp. 23-74, 2018.
15. E. Ciupan, F. Lungu, and C. Ciupan. **ANN Method for Control of Robots to Avoid Obstacles**, *International Journal of Computers Communications & Control*, Vol. 9, no. 5, pp. 539-554, 2014.
16. B. P. Kumar, M. S. Suman, D. P. Samuel, V. Vadivel, and C. Ananth. **Autonomous Mobile Robot Navigation System**, *International Journal of Advanced Research in Biology, Ecology, Science and Technology (IJARBEST)*, Vol. 1, no. 4, pp. 15-19, 2015. https://doi.org/10.2139/ssrn.3025549
17. A. Kuleshov, A. Bernstein, and E. Burnaev. **Mobile Robot Localization via Machine Learning**, *In International Conference on Machine Learning and Data Mining in Pattern Recognition*, pp. 276-290, 2017. https://doi.org/10.1007/978-3-319-62416-7_20
18. B. Li, T. Gallagher, C. Rizos, and A. G. Dempster. **Using geomagnetic field for indoor positioning**, *Journal of Applied Geodesy*, Vol. 7, no. 4, pp. 299-308, 2013. https://doi.org/10.1515/jag-2013-0016
19. M. Ayaz, I. Tvoroshenko, J. H. Baker, and V. Lyashenko. **Modeling the Structure of Intellectual Means of Decision-Making Using a System-Oriented NFO Approach**, *International Journal of Emerging Trends in Engineering Research*, Vol. 7, no. 11, pp. 460-465, 2019. https://doi.org/10.30534/ijeter/2019/107112019
20. Vyacheslav Lyashenko, Syed Khalid Mustafa, Svitlana Sotnik, M. Ayaz Ahmad. **Basic Principles of Decision Making upon Receipt of New Nanomaterial**, *International Journal of Advanced Trends in Computer Science and Engineering (IJATCSE)*, Vol. 8, no. 5, (2019), pp. 2680-2685. https://doi.org/10.30534/ijatcse/2019/124852019
21. Vyacheslav Lyashenko, Syed Khalid Mustafa, Nataliya Belova, M. Ayaz Ahmad. **Some Features in Calculation of Mold Details for Plastic Products**, *International Journal of Emerging Trends in Engineering Research (IJETER)*, Vol. 7, no. 11, (2019), pp. 720-724. https://doi.org/10.30534/ijeter/2019/517112019
22. Vyacheslav Lyashenko, Syed Khalid Mustafa, Irina Tvoroshenko, M. Ayaz Ahmad. **Methods of Using Fuzzy Interval Logic During Processing of Space States of Complex Biophysical Objects**, *International Journal of Emerging Trends in Engineering Research (IJETER)*, Vol. 8, no. 2, (2020), pp. 372-377. https://doi.org/10.30534/ijeter/2020/22822020
23. M. Ayaz Ahmad, Syed Khalid Mustafa, Oleksandr Zeleniy, Vyacheslav Lyashenko. **Wavelet Coherence as a Tool for Markers Selection in the Diagnosis of Kidney Disease**, *International Journal of Emerging Trends in Engineering Research (IJETER)*, Vol. 8, no. 2, (2020), pp. 378-383. https://doi.org/10.30534/ijeter/2020/23822020
24. Irina Tvoroshenko, M. Ayaz Ahmad, Syed Khalid Mustafa, Vyacheslav Lyashenko, Adel R. Alharbi. **Modification of Models Intensive Development Ontologies by Fuzzy Logic**, *International Journal of Emerging Trends in Engineering Research (IJETER)*, Vol. 8, no. 3 (2020), pp. 939-944. https://doi.org/10.30534/ijeter/2020/50832020
25. Svitlana Sotnik, Syed Khalid Mustafa, M. Ayaz Ahmad, Vyacheslav Lyashenko, Oleksandr Zeleniy. **Some Features of Route Planning as the Basis in a Mobile Robot**, *International Journal of Emerging Trends in Engineering Research (IJETER)*, Vol. 8, no. 5 (2020), pp. 2074-2079. https://doi.org/10.30534/ijeter/2020/97852020