PATH PLANNING FOR NON-CONTACT COORDINATE MEASUREMENT MACHINE APPLICATION IN AUTOMOBILE QUALITY INSPECTION PROCESS

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АВТОМОБИЛЛАР СИФАТ НАЗОРАТИ ЖАРАЁНИДА ҚЎЛЛАНИЛАДИГАН КОНТАКТСИЗ МУВОФИҚЛОВЧИ-ЎЛЧАШ МАШИНАНИНГ ТРАЕКТОРИЯСИНИ РЕЖАЛАШТИРИШ

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Аннотация. *Глобаллашув муаммолари нафақат ҳаётнинг ижтимоий ёки сиёсий жиҳатларига таъсир кўрсатади, балки ҳар қандай ишлаб чиқариш тизимлари учун катта муаммоларни келтириб чиқаради. Маҳсулотга бўлган талабнинг бир бирлигига ошиши ва буюртмачининг сифат талабларига мувофиқлиги ишончли ишлаб чиқариш назорат тизимини талаб этади. Маҳсулотлар сифати стандартини такомиллаштириш мавжуд бўлган сифат назорати ва назорат усулларидан фарқли уларoқ такомиллашган усулларга ўтишга таъсир кўрсатади. Мақолада кўриб чиқилаётган муаммо Ўзбекистонда автомобилларни ишлаб чиқариш тизими билан узвий боғлиқ. Бироқ мазкур услубиёт жаҳоннинг турли мамлакатларида саноатнинг турли тармоқлари ва технологияларида қўлланилиши мумкин. Мазкур тезисда замонавий саноатнинг иккита асосий талаблари – вақт ва сифатга мос келиши учун саноат буюмларини мувофиқловчи-ўлчаш машиналарида ўлчашга ишончли ўтиш механизмларини ишлаб чиқишга асосий эътибор берилган.Мазкур тезисда замонавий саноатнинг иккита асосий талаблари – вақт ва сифатга мос келиши учун саноат буюмларини мувофиқловчи-ўлчаш машиналарида ўлчашга ишончли ўтиш механизмларини ишлаб чиқишга асосий эътибор берилган.*

Таянч тушунчалар: *мувофиқловчи-ўлчаш машиналари, автоматлаштирилган лойиҳалаштириш-тизими, ROS, ишлаб чиқариш, автомобилсозлик, робототехника, лазерли сканер қилиш, ҳолатни таҳлил қилиш, энг қисқа йўл, механик детали, асбобнинг марказий нуқтаси, контактсиз мувофиқловчи-ўлчаш машинаси.*

ПЛАНИРОВАНИЕ ПУТИ БЕСКОНТАКТНОЙ КООРДИНАТНО-ИЗМЕРИТЕЛЬНОЙ МАШИНЫ ДЛЯ ПРИМЕНЕНИЯ В ПРОЦЕССЕ КОНТРОЛЯ КАЧЕСТВА АВТОМОБИЛЯ

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Аннотация. *Проблемы глобализации влияют не только на социальные или политические аспекты жизни, но и вызывают большие проблемы для любых производственных систем. Повышение спроса на продукцию в единицу времени и соответствие требованиям заказчика с точки зрения качества требуют надежного контроля производственных систем. Совершенствование стандартов качества продукции влияет на переход к усовершенствованным методам контроля качества и контроля, чем те, которые уже доступны. Проблема, рассматриваемая в статье, тесно связана с системами производства автомобилей в Узбекистане. Однако методика также может быть применена в различных отраслях промышленности и технологиях в разных странах мира. Тезис главным образом акцентирует внимание на том, как раз-*

работать надежный подход к измерению промышленных деталей на координатно-измерительных машинах, чтобы соответствовать двум основным требованиям современной индустрии времени и качества.

Ключевые слова: *КИМ, САПР, ROS, производство, автомобилестроение, робототехника, лазерное сканирование, анализ положения, кратчайший путь, механические детали, центральная точка инструмента, бесконтактная координатно-измерительная машина.*

PATH PLANNING FOR NON-CONTACT COORDINATE MEASUREMENT MACHINE APPLICATION IN AUTOMOBILE QUALITY INSPECTION PROCESS

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Annotation. *Today, the challenges of globalization affect not only social or political aspects of life, but also cause big problems for production systems. Increased demand for products per unit of time and customer satisfaction in terms of quality require reliable monitoring of production systems. Improving product quality standards affects the transition to improved quality control methods. The problem addressed in the paper is closely related to the Automobile production system in Uzbekistan. However, the technique can also be applied in various industries and technologies, in different countries of the world. The thesis mainly focuses on how to develop a reliable approach to measurement of industrial parts on a Coordinate Measurement Machines in order to meet the two main requirements of the modern industry of time and quality.*

Key words: *CMM, CAD, ROS, production, automotive, robotic, laser scanning, position analysis, shortest path, mechanical parts, tool center point, non-contact coordinate measuring machine.*

Quality of products depends on various factors. The products have to be controlled in all phases of manufacturing. The production of automotive parts, medical devices, sport equipment's or any other body parts has to be controlled in all phases of production

Enhancement of product quality standards implies delving into control and inspection methods. Nowadays, most engineers should work with data, which are extracted from CMM, working with mechanical parts. CMMs are versatile instruments used for precision inspection in industry, and their unique properties more than justify substantial investment; nevertheless, uncertainties associated with them are to be reckoned with. A correct statement of measurement uncertainty is nowadays necessary for companies wishing to comply with ISO standards, which requires an effective measurement management and measurement process control

The main problem in the high precision inspection and quality control systems in automobile production plant in Uzbekistan is the fact that they can easily cover the problem with the quality but not the time. By stating this, the thesis specifies the need to decrease the inspection process. Most of the CMMs in the production in Uzbekistan are stationary contact CMMs with high precision that are used to inspect the parts in general for the purpose of variations in the model. They just check the difference with the real world model and nominal model. Also, the time is quit important in the industries that is why they cannot check each model of a car in the automobile production. For instance, Body in White is checked about each 100 car sampling variously or even a car in a day.

The objective of the thesis is to describe the research work carried out to development small scale non-contact inspection process and justifying with low cost method in order to apply it in the production in large scale with real scale model. The system provides a method of comparing a one surface of automobile with the nominal surface CAD model, and thus the ability to pass or fail the item being inspected.

Non-contact inspection

Product inspection within the industries continues to play an important role in the improvement of quality and reduction of scrap. Non-contact inspection systems offer the speed, accuracy and flexibility that conventional methods cannot. Non-contacting sensors provide long term unattended use, due to the lack of sensor wear, and in some cases provide the only option for measurement, where conventional contact techniques may damage and geometrically alter the part to be inspected.

A variety of different inspection systems have been described in the past by a number of researchers [1], giving an indication of the problems associated with this method of inspection. The method of illumination, in particular at an angle to the direction of observation, enables topographical information to be obtained. This ensures that surface features that otherwise are difficult to detect, can be observed.

Harding [2] discusses the current contouring techniques in the manufacturing industry, with descriptions of the basic approaches adopted with 3-D machine vision. A popular approach involves the illumination of the surface examined, with a fringe pattern, observing the effect from an angle. This method of non-contact measurement has been adopted by a number of researchers including Burton and Lalor [3], Halsall [4], Malcolm [5] and Chung [6]. These authors describe methods for determining certain features of the surface examined, with the fringe period and angle known. The effect of projecting a fringe pattern onto a surface is the modulation of the pattern to the surface shape.

However, the research mainly focuses not on the inspection type or technology but rather the approach done on the inspection process of the items. That is why, the important point in the paper is not the type of technology used during the measurement with non-contact coordinate measurement system, but maybe the technique used.

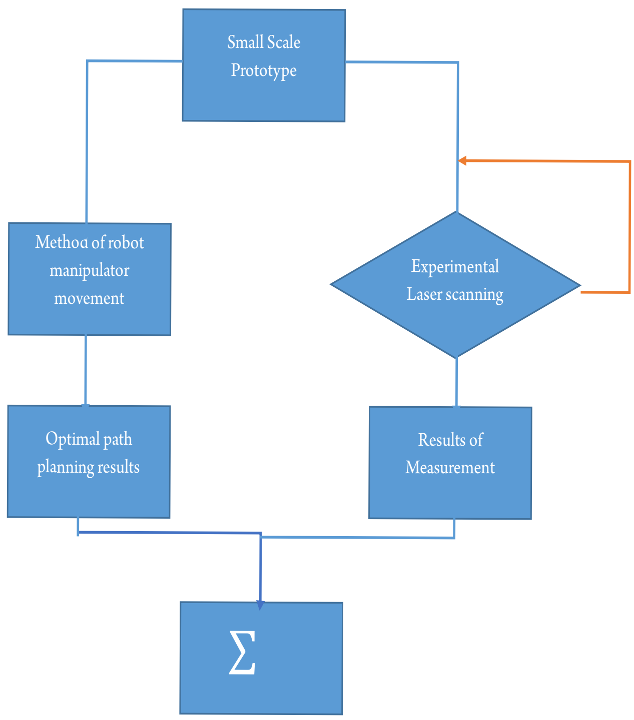
Inspection in Automobile industry

In general, inspection process and quality control system in automobile industry is quite complex issue. Tight production processes lead to the complex methodologies and standards of inspection. Each step of production of automobile is closely bounded up with mechanical, chemical, esthetic, emission and technologic inspectionюMany car manufacturers focus on CMM inspection of Body in White (BIW) because the core structure of an automobile is BIW. Checking the BIW reveals most of the problematic points in the production.

However, the steps after BIW and in particular the finished or fully assembled automobile body inspection is not always the case of inspection with CMMs.

The proposed approach by the thesis is the inspection process or methodology that will enable to inspect each automobile in-line on the final stage of production. The idea is to check the defective points on the sheet metal body of a vehicle, flange and intervals, connection points and even the some inside parts of the vehicle body.

For this purposes the usage of the Contact methods of inspection is not possible due to the fact that contact can damage finished car body panels and also it to much slow process for car manufacturing production rates.



The graph 1. Flow of project

The project

The core idea of the project is to analyze separately the non-contact metrology and robotic manipulator. Manipulator will be used for positioning and appropriate orientation matching for measurements. In this thesis we will mainly emphasis the algorithms and techniques used to move the robotic arms on the surface of the item.

The flow of work can be seen below:

The thesis work analysis mainly the part of flow that is "Method of robot manipulator movement" and Optimal path planning algorithn. After this point the idea was to install a special gripper on the Tool Center point of production robot manipulator that would scan the surface of an items.

The most important point in scanning is the positioning method and principles behind the Robot manipulator movement.

For this purpose we have used the Universal Robot or UR5 that is perfectly fits to the research work as it is small scaled version of big production manipulators. The idea was to use the open source products in order to move and apply movement from points in remote control (PC and Python code).

Pic.1 Universal Robot UR5 [14]

ROS

ROS (Robot Operating System) provides libraries and tools to help software developers create robot applications. It provides hardware abstraction, device drivers, libraries, visualizers, message-passing, package management, and more. ROS is licensed under an open source, BSD license.

Nodes: Nodes are processes that perform computation. ROS is designed to be modular at a fine-grained scale; a robot control system usually comprises many nodes. For example, one node controls a laser range-finder, one node controls the wheel motors, one node performs localization, one node performs path planning, one Node provides a graphical view of the system, and so on. A ROS node is written with the use of a ROS client library, such as roscpp or rospy.

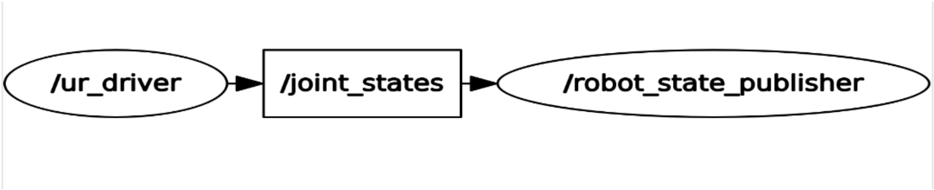
The ur-modern-driver metha-package

The ur-modern-driver package is special created toolbox for communication of ur5 with the ROS system. It works according to the schematics of creating a nodes, services and client systems that controller the UR5 will work.

Here below one can see the topics launched with the launch of **ur_moder_driver**:

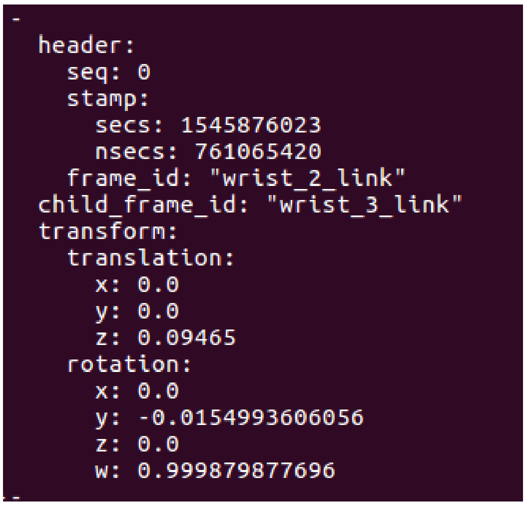
/tf
/tf_static
/tool_velocity
/ur_driver/URScript
/ur_driver/io_states
/ur_driver/joint_speed
/wrench

However, As one can see when we launch ur_moder_driver we mainly launch **publisher-sucscriber** system called **/ur_driver** and **/robot_state_publisher** that is depicted below in the figure one can see below:



Graph 2. Publisher-subscriber node

But, this does not mean that there is no other topics and nodes working. This just means that there is a subscriber for the node to listen the data. There is also a /**tf** that gives the position of End Effector according to schematics: X, Y, Z and Quaternion notation in qx, qy, qz, w:



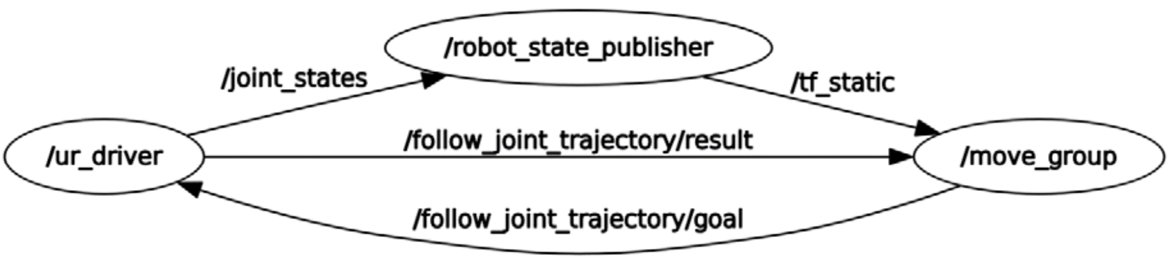
Pic.2 Coordinate data of UR5 from ROS platform

In this way we start the connection between our robot and ROS ecosystem and from this point on we can write the python or cpp codes to control our robot.

But, in order to ease our problem a MoveIt packages for Universal Robot System was created:

MoveIt package is specially created package to incorporate the latest advances in motion planning, manipulation, 3D perception, kinematics, control and navigation. For running the MoveIt node you need to launch roslaunch ur5_moveit_config ur5_moveit_planning_execution.launch after running ur_modern_driver

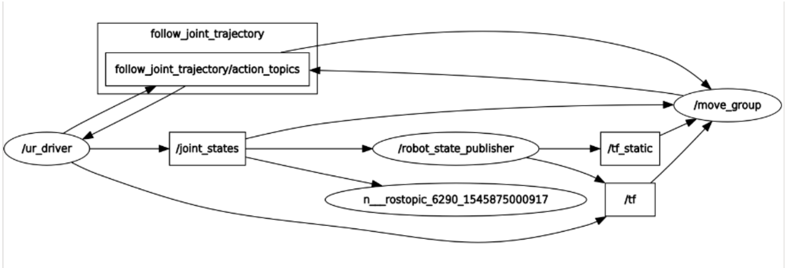
After the launch the node graph changes according to the scheme below:



Graph 3. After application of MoveIt package on UR5

As one can see, there is additional node /move_group that subscribes to /tf_static, /follow_joint_trajectory/result and /follow_joint_trajectory/goal it has actually the same format as /tf but it gives true value every time than the machine moves and transformation are in process.

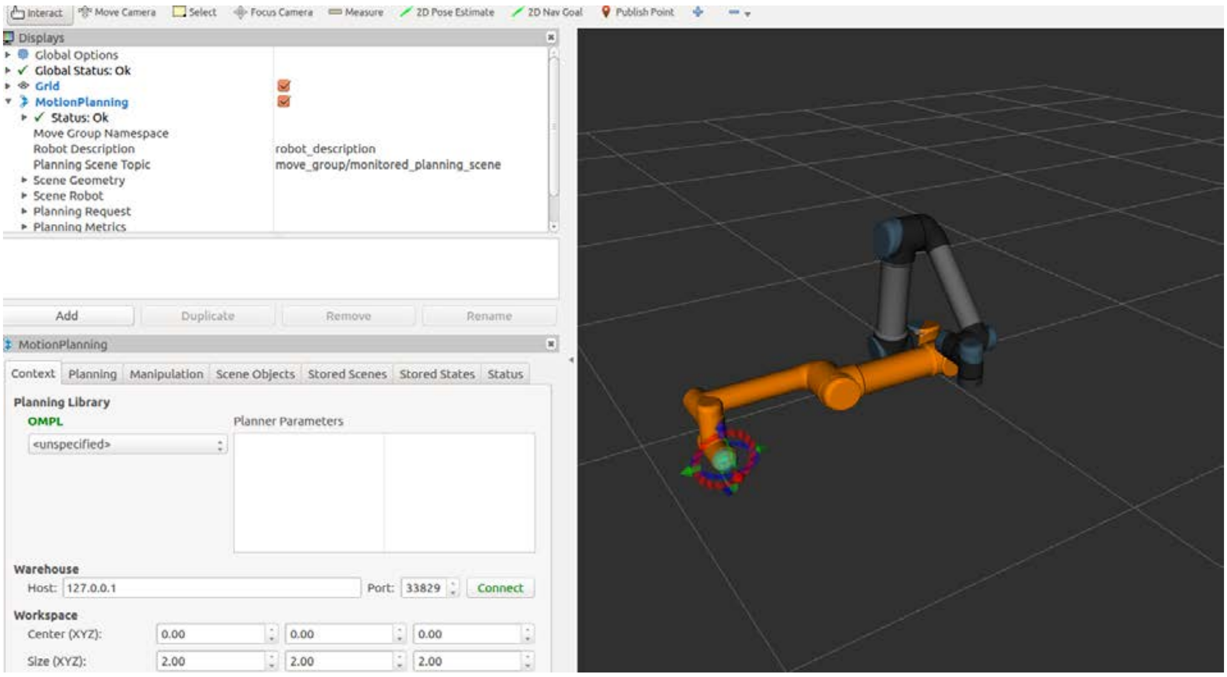
The picture below is the picture of all the active /topics and nodes in process. The joint trajectory action is a node that provides an action interface for tracking trajectory execution. It passes trajectory goals to the controller, and reports success when they have finished executing. The joint trajectory action can also enforce constraints on the trajectory, and abort trajectory execution when the constraints are violated.



Graph 4. All nodes after applying moveit

While the move_group node is one of the main important node inside the move_it multi package that mainly runs the whole robot applying all the methods available inside the robotics.

As one can see from the above picture, a number of different topics are available inside the move_group nodes. User can adjust the parameters of that type of OMPL (Open Motion Planning and Library) algorithm can be used and take all the information about the trajectory execution, status, results and etc…



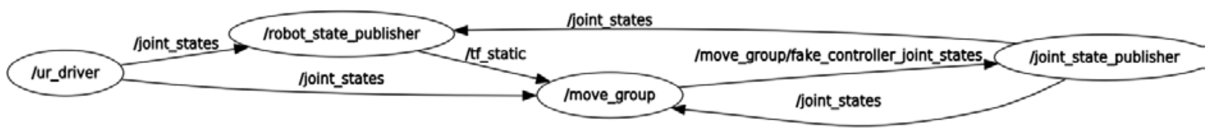
Pic. 3 Real-time simulation with RVIZ

These special topics inside the moveit package is created for the ordinary process of pick-and-place for the manipulators. Because, it is the basic task of manipulators in the industry.

In order to visualize all the process we are doing and maybe also to execute directly from ROS we can also use the RVIZ[3] tool inside the ROS. By running $ roslaunch ur5_moveit_config demo.launch.

It will run already defined ur5 description with the all joints and links created for your easy use. User can see the RVIZ below that follows the real robot position and configurations

This launch file opens up the motion planning scene with all the available tools inside like OMPL, Camera marker, range finder and etc…



Graph 6. Movement of robot through ROS

After launching the RVIZ the picture is little bit different, as a new additional node is added namely /joint_state_publisher that subscribes to /fake_controller_joint_states from RVIZ controller by Laptop and publishes that into /robot_state_publisher

Here in the picture all the ovals are Nodes while the rest are topics. So as you can see n_rviz_a307_LAPTOP works as publisher node that publishes into move group and then according the next scheme it works again.

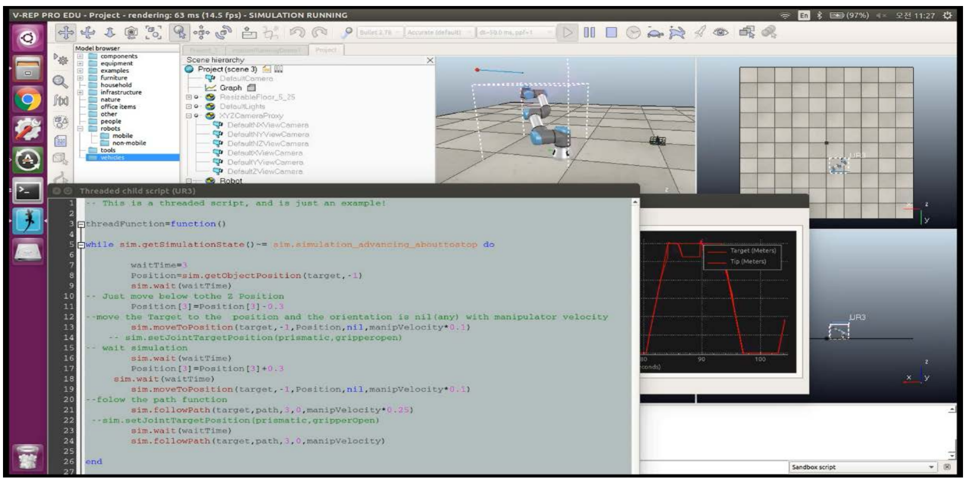
The problem was still to find optimal solution or algorithm that would enable finding the smallest path between the points in the manipulator movement.

For the project RRTconnect algorithm was used as it was designed for robotic manipulators. the idea behind finding the smallest path was in weight system:

Comparing the sums of the smallest paths according to the weight:

SUM of Angles = $a1^{*}\,\theta1 + a2^{*}\,\theta2 + a3^{*}\,\theta3 + a4^{*}\,\theta4 + a5^{*}\,\theta5 + a6^{*}\,\theta6$

The angles θ is the robot axis angles and according to the MIN that is the first loop result is compared while the coefficients are the changeable values.



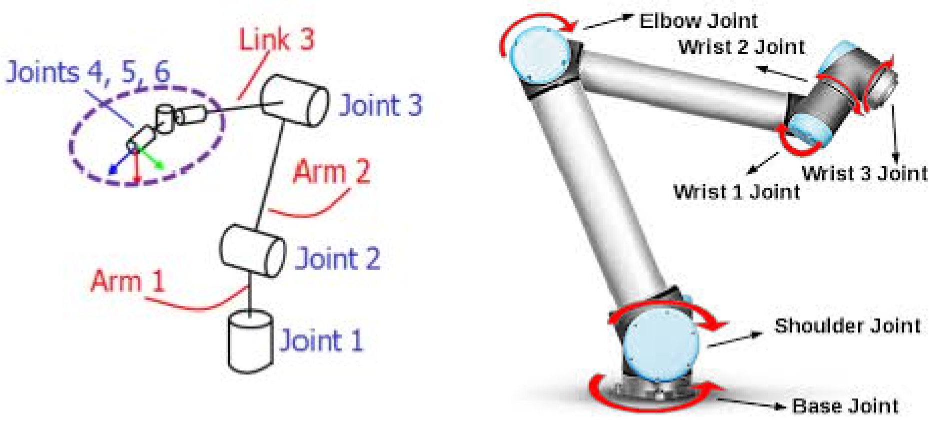
Pic 4. Simulation of parameters with VREP

The simulation with the VREP by changing the parameters of path planning algorithm was done according to the schematics below. The parameters here are the weights of the function.

Simulation results on parameters							
# Trials	a1	a2	a3	a4	a5	a6	LTCP
1	156,5	55,05	36,2	24,45	6,05	112,65	18,8
2	156,55	54,75	35,8	24,5	6,3	112,55	18,85
3	156,8	54,25	35,45	24,3	6,1	112,75	18,7
4	156,45	54,8	35,75	24,35	6	112,7	18,95
5	156,8	54,35	35,6	24,45	5,8	112,5	18,6
6	156,7	54,75	35,65	24,55	5,85	112,69	18,9
7	156,65	54,9	35,65	24,6	6,1	112,8	19
8	156,8	54,9	35,7	24,55	6,1	112,85	18,85
9	156,5	54,8	35,45	24,45	5,8	112,8	18,75
10	156,4	54,75	35,65	24,65	5,75	112,75	18,65
11	156,75	54,65	35,75	24,45	6,15	112,7	18,85
12	156,65	54,8	35,9	24,5	6,3	112,5	18,8
13	156,7	54,5	36,05	24,7	6,05	112,65	18,85
14	156,7	55,15	35,75	24,65	6,1	112,4	18,85
15	156,75	54,15	35,55	24,75	6	112,54	18,65
16	156,8	54,6	35,6	24,5	5,95	112,45	18,75
17	156,45	54,55	35,6	24,5	6,15	112,3	18,95
18	156,65	54,65	35,65	24,45	6,05	112,3	18,85
19	156,45	54,75	35,8	24,45	6,3	112,35	18,75
20	156,6	54,8	35,7	24,5	6,1	112,65	18,65
Mean	156.5	54.7	35,71	24.42	6,05	112,59	18,80
Standarddeviation	0.21	0,18	0,20	0,16	0,10	0,25	0,15

Table 1. Weight table

By changing the parameters of for the angles we actually change the weight for each angle rotation. The weight of each axis rotation is defines the movement.



Pic 5. Joint-link system

We need the shortest path between the two points on the space that is why we need to consider that the movement of the first axis on the base will greatly influence the position change on the TCP.

Conclusion

Positioning and path planning algorithm for the non-contact coordinate measuring machine with robot manipulator is key issue. There is almost 50 points in different coordinates of the vehicles in the inspection process of the automobile at GM Uzbekistan automobiles. Path planning between the points plays an essential role as it closely bounded up with the production time.

Nowadays, the quality control process is thought to be the bottleneck process that means that the lines throughput cannot exceed the rate of quality control point.

Results from a small-scale model of future-industrial robot has shown that it can be easily implemented with the big-scale real time robotic arm CMM. The application of non-contact CMM greatly enhances the available methods of inspection of an assembled car technology giving a number of advancements that is listed below:

- Total elimination of an operator's error and interaction in the inspection process of assembled car (Automation of a process)
- Increase of the speed of inspection process compared to the existing operator visual analysis
- Leveling up the precision standards on the car body, increase of quality of car body surface
- Availability of online results on computer servers

Implementing this kind of tool in the GM Uzbekistan plant will not just increase the quality of the products produced, but maybe help to apply automation in the quality control system of GM Uzbekistan and decrease the cycle time of each car produced.

Quality of products depends on various factors. The production of automotive parts, medical devices, sport equipment's or any other body parts has to be controlled in all phases of production.

The aim of the thesis is to show a new approach toward the enhancement of the production process and inspection systems. Future project that is going to be based on this small scale project and thesis will totally change the inspection process in the plant.

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References

1. *Lei Q., Wisse M., Fast grasping of unknown objects using force balance optimization. IEEE International Conference on Intelligent Robots and Systems. – 2014. – pp. 2454-2460.*
2. *Trepagnier P., Recent developments of visual gaging. SME VISION, 1985. – pp. 3-12 to 3-23.*
3. *Thomason R.L., High speed machine vision inspection for surface flaws, textures and contours. SME VISION, 1986. – pp. 5-51 to 5-61.*
4. *Schurr G.W., Applying a low cost single dimension vision system for surface flaw and package inspection. SME VISION, 1986. – pp. 1-15 to 1-27*
5. *Cheraghpour. F., Moosavian S.A.A, and Nahvi A., Multiple Aspect Grasp performance index for cooperative object manipulation tasks. IEEE/ASME Int. Conf. on Advanced Intelligent Mechatronics, 2009. – pp. 386-391.*
6. *Eslamy M., Moosavian S.A.A, Dynamics and Cooperative object Manipulation Control of Suspended Mobile Manipulators. / J Intell Robot Syst Springer Science+Business Media B.V, 2010. – pp. 1-19.*
7. *Harada, K. Kaneko K., Kanehiro F., Fast Grasp Planning for Hand/Arms Systems Based on Convex Model. IEEE International Conference on Robotics and Automation, 2008. – pp. 1-7,*
8. *. Karimi M, Moosavian S.A.A., Modified Transpose Effective Jaco- bian Law for Control of Underactuated Manipulators. / Koninklijke Brill NY, Leiden and The Robotics Society of Japan, 2009-pp. – pp. 605-626.*
9. *Zeng G., Hemami A., An overview of robot force control. / Robotica, Cambridge University Press, volume 15, 1997. – pp. 473-482.*

10. Moosavian S.A.A., and Papadopoulos E., Cooperative Object Manipulation with Contact Impact Using Multiple Impedance Control. / International Journal of Control, Automation, and Systems, 2010 – pp. 314-327.

11. Bloss R., Innovations like two arms, cheaper prices, easier programming, autonomous and collaborative operation are driving automation deployment in manufacturing and elsewhere. / Assembly Automation No. 4, Vol. 33, 2013. – pp. 312-316.

12. Schrimpf J., Lind M., Mathisen G., Real-time analysis of a multi-robot sewing cell. / Industrial Technology (ICIT), 2013 IEEE International Conference on, Feb 25-28, 2013. – pp. 163-168.

13. Guerin K.R., Lea C., Paxton C., Hager G.D, A framework for end-user instruction of a robot assistant for manufacturing. / Proceedings – IEEE International Conference on Robotics and Automation. – June, 2015. – pp. 6167-6174.

14. UR5 picture taken in KITECH, Korean Institute of Industrial Technology

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